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The reintroduction of sail for marine commerce: and the consequent effects upon small port economy and trade routing

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THE REINTRODUCTION OF SAIL FOR MARINE COMMERCE: AND THE CONSEQUENT EFFECTS UPON SMALL PORT ECONOMY AND TRADE ROUTING

A Thesis

Submitted to the Graduate School of the University of Notre Dame in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Environic Design

by

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PREFACE

This thesis represents a personal milestone in my interest and involvement in ships and the sea. My appreciation and respect for the power of wind and water evolved from long periods at sea during thirteen years of service in the U.S. Navy. Experience in sailboats on Lake Michigan has taught me the practical application of wind power on the most basic terms of the human/nature relationship. I have gained, through extensive study, an in-depth understanding of sailing ships and their development. These experiences, linked with my deep concern for the natural earth and its future, have resulted in this thesis.

One who has not spent his life in sailing ships, but writes about them, is open to criticism from those who have. I have endeavored not to speak with authority where I have none, but have drawn upon knowledge of the experts when necessary. There is no substitute for experience in wind ships, and I have the greatest respect for those who have it.

I believe that the public interest and a willingness to accept commercial sail in both romantic and practical terms are at peak levels today. Therefore, my ongoing interests include: 1) the cultivation of sail consciousness in the U.S. Navy, 2) the development of commercial sail under Navy and private auspices, and 3) the advancement of sail consciousness in the public as a fundamental

national economic obligation with respect to environics, small port economy, and gratifying, profitable employment in the shipping and shipbuilding industries.

I would be remiss if I failed to thank Professor Patrick Horsbrugh for his long hours of assistance and his unparalleled ability to provide motivation to continue. Often I arrived at his office "in the doldrums" and left in a "gale" of enthusiasm. Thanks are due also to my readers Professors Kenneth Brehob, William Leahy, and "Gus" Strandhalen for their assistance, critical comments and encouragement.

INTRODUCTION

The ocean, the wind, and the land are inseparably linked in an environic triad which encompasses mankind. Human history confirms a dependence upon wind and water for man's discoveries, trade, and migration. In few other relationships with natural forces is man so totally dependent upon the elements. Yet, this utilization of wind and water is profoundly rational, and man learned to use them well. Together, wind and water form reciprocal elements of a transportation system, the conveying medium and the driving power.

The Industrial Transformation led to the near abandonment of wind as the driving force for ships. Cheap and abundant coal and oil resulted in neglect of the proven technology of wind power at sea. Modern man is transfixed by the power of fossil fuels. While once viewed as a panacea, their uses are governed today by a series of perplexing economic, political, and environmental constraints.

The term wind is used herein as the force due to air movements in the earth's boundary layer, as opposed to upper atmospheric or solar wind. The essential element is the force, rather than the air medium itself.

The use of wind for propulsion is an essential, practical discipline. The wind is free, subject to no economic controls. It knows no political influence. There can be

no wind "embargo." It can be used even if contaminated. The wind does not depend upon any processing or treatment to make it usable. It does not have to be stored, containerized, pumped, heated, cooled, sampled, or transferred about. The wind is inflammable. Once "used," the wind continues its ceaseless swirl about the earth, and the term depletion does not apply. Nor does its use spawn any polluting byproducts. Most forces are subject to measurement and control; the wind can only be measured, not controlled.

The ingenuity of man led to the development and refinement of the sailing ship as a highly efficient mode of transport. Then man's absurd preoccupation with fossil fuels and mechanical propulsion led to the near abandonment of sail on a commercial basis. Only a very slender continuing thread remained. Once again conditions appear ideal for the employment of wind-powered ships. Fuel costs are soaring and show no prospect of stabilizing. Fuel represents the most expensive single operating cost of any motor-driven cargo vessel. Ship size has grown beyond reason, "their dimensions being one of the technological audacities of the century."[1]

There exists a great deal of worldwide interest in the reintroduction of wind power for commercial cargo ships in the size range of 15,000 to 50,000 DWT.[2] In the United Kingdom, HM government, the Royal Institution of Naval Architects, and several universities have shown great

interest, and have sponsored symposia on the future of commercial sail.[3]

In the United States, the interest is also present, but at a more decentralized and uncoordinated level. The U.S. Congress in 1976 passed House Concurrent Resolution 444, which called for "increased federal efforts to prove the commercial viability of sailing ships."[4] The U.S. Maritime Administration has sponsored two studies into the feasibility of sailing ships for the U.S. merchant marine. Another significant milestone was the recognition of the future of sail in the February 1980 Marine Engineering/Log,[5] a highly respected and widely read magazine in shipping circles.

Japan has recently shown interest in wind power by equipping a small test vessel with auxiliary sails. Mr. William Warner, President of Dynaship Corporation, while contemplating the future of modern wind-powered ships, has quipped, "The English will talk about it forever. The Americans will study it to death. But the Japanese will go ahead and do it."[6]

Proposals for modern wind-powered ships which have been spawned by the interest cited above are based upon the concept of lower operating costs, due to the decreased fuel usage. This is a commendable goal, and certainly attainable. But unknowingly, the building of these ships will provide the participating nations with vessels which can continue operation upon a loss of fossil fuels, due to

depletion, war, or political chicanery.

In the short run, sail is not a panacea for the economic ills of the shipping industry. Even in 1980 there is more interest in reducing running costs at sea by developing more efficient engines than by returning to wind power. Admittedly, sail is not applicable in all trades. Wind propulsion appears best suited for vessels operating in the bulk trades over long distances. The development of modern wind-powered ships should parallel and complement the search for cheaper and more efficient conventional ship propulsion. Recent activities in the latter area include development of slow and medium speed diesel engines, use of waterborne coal slurry, and improvement of steam turbine propulsion systems.

In the final analysis, the marine transport industry is virtually committed to petroleum based fuels for commercial operations. Nuclear power for commercial cargo vessels failed in the U.S. and Japan. It has only been successful in naval application, where the ultimate nuclear technologies have been developed. With the continued upward spiral of fuel prices, nuclear power may again draw the interest of commercial shipowners. The associated problems of radio-active containment and public sentiment will be, in this case, greater considerations than cost. Should nuclear power be used for commercial ship propulsion, the U.S. Navy's prestigeous nuclear power program should be used as

a model for its operation and introduction.

The other alternative is wind power, which reached its ultimate development early in the twentieth century, and now stands on the threshold of rebirth. Modern wind-powered cargo ships will appear in the world's merchant fleets in the near future, but a slow start is anticipated. The shipping industry has always been characterized by conservatism. Economic pressures, however, will generate action by the cost-conscious and fuel-short industry. The world will watch intently as the first modern sailing ships set sail and compete with their motor-driven counterparts. Ill-designed, hastily-conceived efforts will undoubtedly fail. A carefully contrived plan of action, according to the principles discussed in this thesis, will be essential to ensure the economic and technical success of sail power.

Chapter I of the thesis reviews briefly the development of sail from its inception to its near deathblow from steam. Several striking characteristics which led to its peak of efficiency are discussed. This zenith of development is significant as a logical point from which to expand sail technology for modern ships.

A comprehensive review of existing sailing cargo vessels and current proposals for such ships are presented in Chapter II. These proposals are centered around three separate philosophies. First, those based upon the design of traditional sailing ships are discussed. The next section

analyzes those proposals based upon technological innovations. Thirdly, the use of sail as a means of auxiliary power is surveyed.

Chapter III deals with the economics and legalities of the reintroduction of sail. These are subjects which are often neglected in proposals for modern sailing vessels, yet have a great significance toward their success.

The physical influence of sail on the littoral area is considered in Chapter IV. The potential revitalization of smaller ports and shipyards is an exciting consequence of a widespread application of sail power. The unique ship/land interface characteristics of sailing are analyzed. The human element, in both ship manning and sail training, is also considered here.

Weather routing and its advantages for modern wind-powered ships are examined in Chapter V. The favorable impact of remote sensing and communications technology on sailing ship weather routing is emphasized.

In summary, modern wind-powered cargo vessels are herein studied from an environic perspective. The basic philosophy of sail power is based upon environic sensitivity and an obligation toward the conditions of the natural and built environments. Interdependencies between sailing ships and the social and industrial fabric with which they relate are considered of primary importance. Each physical design and social decision regarding modern sailing ships

will have environic consequences. Maritime planners are obligated toward the cultivation of quality and stability in this regard. The ultimate intent of this thesis is the advancement of sail consciousness in the public as a fundamental national economic obligation with respect to environics, small port economy, and gratifying, profitable employment in the shipping and shipbuilding industries.

FOOTNOTES

[1] Noel Mostert, Supership, (New York, 1974), p. 15.

[2] DWT is an abbreviation for deadweight tons, which is a common reference to size of modern cargo ships. It represents, in tons, the difference in displacement of a vessel when light (unloaded), and when fully loaded with cargo. A different measurement is a vessel's registered tonnage, or that shown in the vessel's certificate of registry. The gross registered tonnage (grt) is a total internal cubic measurement of a given number of "tons," or units of 100 cubic feet, less such space or spaces in which no fuel, cargo, or stores are carried. From the official grt, the net registered tonnage (nrt) is arrived at by deducting certain spaces, including crew's quarters, storerooms, chartroom, wheel-house, superstructures for use of passengers, and a generous allowance for the propulsion plant according to internationally recognized rules governing ship measurement. Source: W.A. McEwen and A.H. Lewis, Enclyclopedia of Nautical Knowledge, (Cambridge, Maryland, 1953).

[3] November 27, 1975: Symposium on the Future of Commercial Sail, sponsored by the Royal Institution of Naval Architects Small Craft Group, London.

February 26, 1976: Symposium on Technical and Economic Feasibility of Commercial Sailing Ships, sponsored by Liverpool Polytechnic, Department of Maritime Studies, Liverpool.

June, 1979: Symposium on the Viability of Commercial Sailing Ships, sponsored by the Department of Industry's Ship and Marine Technology Requirements Board, London.

[4] Cindy Buckley, "Return of the Wind-powered Ships," Sealift, May, 1976, p. 23.

[5] Greg Ochevka, "Sail Cargo Ships to Arrive in 1980's?," Marine Engineering/Log, February 1980, pp. 50-55.

[6] Greg Ochevka, "Sail Cargo Ships to Arrive in 1980's?," Marine Engineering/Log, February 1980, pp. 50-55.

CHAPTER I

A REVIEW OF THE DEVELOPMENT OF COMMERCIAL SAIL

The profound consequences of wind propulsion on the history of world civilization are well recorded. For millenia, sail power was the singular means by which man transported himself and his goods across oceans. The sail was essential to the human phenomena of discovery, trade, and migration.

Mankind's initial diffusion from the cradles of civilization was accomplished by his power or by that of his domesticated animals. When he reached the littoral, watercraft powered by the paddle or oar were sufficient for short voyages, such as those within the Mediterranean and along coastal Europe. It was harnessing of the wind for water transport - a notion of profound significance - which released man from his previously coast-bound world. Phillips-Birt theorizes on the beginnings of sail by suggesting that a leaf of a palm tree held aloft may have served as the first sail.[1] He cites a design on a predynastic Egyptian vase, circa 5000 B.C., upon which he bases this assumption. Phillips-Birt also suggests that the origin of sail may not have been the previously supposed Mediterranean, Red Sea, or Persian Gulf, but the Indian Ocean.[2] From here it spread to other parts of the known world, including Northern Europe, where sails were probably first used by the Scandinavians about 600 A.D.[3]

Ships, sails, and the skills of seamanship continued to improve and eventually oceanic voyages were undertaken. The Vikings had made voyages under sail to Iceland, Greenland, and Vinland by the eleventh century.[4] Yet, it wasn't until the medieval period that northern Europe surpassed the south by developing the three-masted sailing ship.

The beginning of the Age of Discovery, heralded by the early voyages south along the west coast of Africa, depended upon this type of ship. The ensuing discoveries of Diaz, de Gama, Cabral, Columbus and Magellan are well-known. "Clearly the invention of the sail is the most crucial event in the story of seamanship, paralleled only by the development of mechanical power afloat."[5]

EARLY SAIL DEVELOPMENT

The great age of sail spanned the five centuries between 1400 and 1900 A.D. By the beginning of this period, sail had developed to a degree whereby man could depend upon it for transoceanic voyages. As early as the seventh century, Vikings had ventured to Iceland, then in the tenth century to Greenland and to Vinland early in the eleventh century.

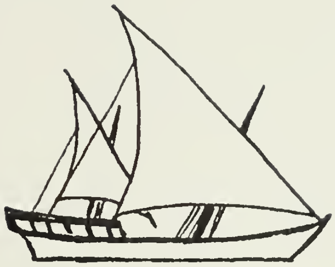
The Ships

The Vikings' seaworthy vessels, called knarrs, were single-masted and rigged with one square sail. During the evolution of these vessels, the lateen rig was developing

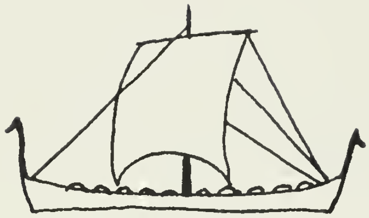
in the Mediterranean. These ships were distinguished by a large triangular sail rigged fore and aft on the mast and supported by a long, slanting yard. This rig could sail much closer to the wind than the square sail of the north. (FIGURE 1).

By 1400, a synthesis of these rigs resulted in the caravel, a three-masted vessel of either lateen rig or a combination of square rig and lateen. These vessels proved ideal for the African coastal explorations organized by Prince Henry the Navigator. As voyages became longer, larger, more seaworthy craft were necessary for additional crew and their supplies and trade goods. This need was provided by the nao, a three-masted vessel of 100 tons or more. It was square-rigged on the foremast and the main-mast and included a main topsail. The mizzen mast retained the lateen rig for working the vessel into the wind. The fact that Magellan's fleet was composed entirely of nao's is indicative of the confidence which mariners had in these vessels. In fact, the nao heralded the modern full-rigged ship. (FIGURE 2).

> By the middle of the sixteenth century, these three-masted, multisail vessels, with their distinct overhanging forecastles and round sterns, were accepted as the most seaworthy vessels afloat. For all their ungainliness, they were the ship of the future, and every successful oceangoing merchantman or warship built in Europe for the next three centuries would hark back to them as progenitors.[6]



Lateen Rig



Square Rig (Knarr)

FIGURE 1.

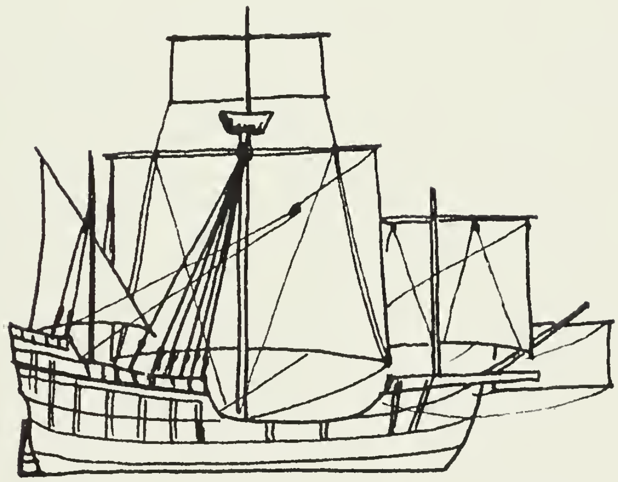


FIGURE 2. Nao

Ships continued to increase in size. During the sixteenth and seventeenth centuries they were used not only for exploration and trade, but for conquering empires as well. Shipbuilding became a science in the seventeenth century, and the British were recognized as the master builders. It was during this period that ships assumed a now familiar profile, with three sails per mast - mainsail, topsail, and topgallant. In 1760 a fourth sail, the royal, was added.[7] This basic sail plan was never fundamentally changed. Minor changes, such as splitting topsails and topgallants into two units for ease of handling, appeared much later during the post-clipper era. Even though improvements, driven by economics, were incorporated in sailing ship design, the final evolutionary period of sail awaited the nineteenth century. "Surprisingly enough, prior to the French Revolution, neither naval architects nor those in command of warships or merchantmen displayed any great regard for speed."[8] In the quest for speed, the Americans took the lead. Howard I. Chapelle, the renowned maritime historian has written: "The mania for speed had slowly been infecting American seamen and shipbuilders since 1790."[9] This led to the introduction of the regular packet ships in 1818, then to the clipper ship era during the mid 1800's, when speed was revered at the expense of other qualities, such as capacity, cost, and safety.

Speed was, in effect, prestige. There is an interesting

dichotomy in this argument. First, speed meant seamanship of the highest order, which required a talented master who was not timid about "carrying on."[10] Efficient teamwork by a large crew was another prerequisite. Secondly, speed meant time, and to the owner and the shipper, this was measured in economic terms. Today, although still prestigeous, speed is not everything. In the days of the clippers, speed was costly, but this cost was tempered by the desire for a quick passage. In spite of the fact that speed achievement is even more technologically feasible today, in any endeavor, the tremendous costs involved prohibit its practicality. Efficiency, especially in terms of fuel usage, is the watchword in today's shipping industry.

This sense of economy was also prevalent in the post-clipper era. During the latter part of the nineteenth century a balance was struck between speed and cargo capacity and operating costs. The results were the finest sailing cargo ships that the world had seen.

Trade Routing

The first sea voyages under sail were most likely fraught with uncertainty, and good fortune must have played a role in a vessel's safe arrival at its destination.

> Men contrived to evolve the first arts of seamanship, the handling of their . . . craft when wind brought waves, and when inshore currents swirled them from their course. They had to learn how to react to all the multitudinous effects of wind on the water through which they sought to drive their boats.[11]

Observant of natural phenomena in his environment, man learned to use the prevailing winds to his advantage. By trial and error, seamanship emerged as an accomplished art over the centuries. Surely mariners didn't know why the winds blew as they did, but the knowledge that they did, in itself, would suffice for ages. "The Vikings had learned very early how to make westing in the high latitudes of the North Atlantic with their square-sailed big boats. . . ."[12] Certainly the peoples of the Indian Ocean basin and the Western Pacific took early advantage of the Monsoon conditions, as they still do today.

A significant event in the history of seamanship was the organized attempt to collect and record data on wind and sea conditions. "In this . . . the Portuguese were the true pioneers."[13] Each voyage then helped to ensure the success of the next. Captain James Cook's observations led to serious study of the world's weather systems. The first wind and current charts appeared in 1847, largely as a result of Lieutenant Matthew F. Maury's compilation of ship's log data.[14] There were no weather forecasts in those days, and ship's masters had to rely on these charts, augmented with their own interpretation of the local

weather conditions. Some were more skillful than others in this regard. The former generally averaged shorter passage times from port to port. Villiers has written of the skill of Robert Hilgendorf, who sailed big ships around Cape Horn during the last days of sail.[15] He would study records of hundreds of sailing ship voyages at the Hydrographic Office. By applying this knowledge, he would make consistently good passages.

Familiarity with the prevailing winds such as the trades, the westerlies and the monsoons by a ship's master was assumed. The skill, however, was the ability to predict the extremities of these wind zones during a given time of year. Thus, ships could avoid areas of calm to the maximum extent, as well as sail routes where the wind was favorable.

THE ZENITH OF SAILING SHIP DEVELOPMENT

Each of the following ship types made a major contribution toward the ultimate development of sail power as a mode of ocean transport. One particular characteristic can be identified for which each was renowned. It must be borne in mind that these ships were faced with the competition of steam. A sailing ship had to pay her way and show a fair profit, or she must fail. The evolutionary process discussed below was, therefore, driven by economics. The sailing ship was indeed economically successful well into

the twentieth century.

Sailing Packets

During the early nineteenth century, sailing ships involved in general trade sailed in accordance with an informal schedule. When a ship completed loading of its cargo, or was convinced that no additional cargo was forthcoming, it would sail. This undoubtedly caused a great deal of anxiety among any passengers who may have signed on.

In the first week of January, 1818, two packet ships departed at specified dates to begin the first scheduled packet service in the North Atlantic.[16] The ship courier sailed from Liverpool for New York and the James Monroe departed New York for Liverpool. The line was to become the "Black Ball" line, which advertised scheduled sailings from Liverpool and New York on the first and fifth day of each month, respectively. Thus, these packets introduced regularity of departure, and "were the direct ancestors of the great steamship lines of today."[17]

The Black Ball and other packet lines figured significantly in the history of the North Atlantic Arena from 1818 until 1878.[18] During the height of the packet era, 1818-1838, these lines carried the latest news and mail, passengers, and the most valuable freight between the United States and Europe. Between 1838 and 1858, the sailing packets began to feel the competition of steam. The

latter first captured the mail service, then the passengers and fine freight. In the period 1858-1878, sailing packets were reduced to hauling heavy freight, coal, and iron. After this period, the steamship became the primary carrier of cargoes on the U.S. to Europe route.

Clipper Ships

The clippers have undoubtedly received more publicity and have been romanticized more than any other type of sailing ship. They were built for speed, but not every clipper made a fast passage at every attempt. The majority of record passages are held, however, by clippers. The record speed attained by any American-built sailing ship was reported by Cutler as 22 knots (for short periods) by the clipper Sovereign of the Seas during a passage from London to Sydney in 1854.[19]

The term clipper has become a misnomer for any ship that gave the appearance of speed. MacGregor lists four characteristics that should be present to qualify a vessel as a clipper:[20] a fine-lined hull, an emphasis on streamlined appearance, a large sail area, and a daring and skillful master. The last was necessary to realize the potential of the first three.

The forerunner of the true clipper was the Baltimore clipper, a schooner or brig built primarily for speed. In the early 1840's, this rig was expanded to that of a

three-masted full-rigged ship which retained the fine lines of the Baltimore clipper's hull. With these ships the Americans entered the China tea trade, in which the British had been engaged with relatively slow, bulky ships. "Despite the improvements in some British ships, there is no doubt that in the 1840's and the early 1850's the American-built clipper ships were the fastest and most successful."[21] The California gold rush gave the American clipper ship an additional impetus as the demand for transportation to the west coast increased.

The British, spurred by American competition in the tea trade, began producing tea clippers in the early 1850's. Soon they excelled, and by the 1860's were building composite clippers, with iron frames and wooden sheathing. These vessels were sturdier and less vulnerable to age than the all-wood American clippers. These ships gained fame in the Zenith of tea clipper racing from 1859 to 1872.[22] These voyages were, in fact, races, as the first cargo of tea arriving each season rated a substantial premium. After 1872, there was no real racing in the tea trade amongst the clippers.[23] The first teas to market were then brought through the Suez Canal by steamships. For several years thereafter the clippers, many now built of iron, continued in the Australian wool and emigrant trades.

Eventually, these splendid clippers were either wrecked, retired, or became lost by neglect at forgotten moorings. The glorious days of the tea trade were over

and the clippers were not replaced. Their legacy of speed under sail, however, shall not be forgotten. Fortunately, one remains: the fully restored Cutty Sark at the National Maritime Museum, Greenwich.

Down Easters

These vessels were strictly a product of the United States, specifically, the "down east" states of Maine, Massachusetts, Connecticut, and New Hampshire. They were built between the years of 1868 and 1893,[24] and thus were successors to the clippers. American shipbuilders, taking advantage of the forests of these regions, built their vessels of wood. Though not as fast as the clippers, the down easters were capable of excellent speeds. More importantly, their cargo capacity was greater than that of their predecessors. "They represented the highest development of the American square-rigged ship and were capable of a good turn of speed, with an ease of handling which allowed a small crew and consequently low operating costs."[25]

The primary livelihood of these ships was carrying grain from San Francisco to New York and Liverpool. Since this trade involved a passage around Cape Horn, the ships also became known as "Cape Horners." Other trades in which they were employed were lumber, coal, sugar, and Chilean nitrates.

The down easters carried on in the forefront of

American shipping for twenty-five to thirty years. Although their operating cost was considered to be low, the ship rig[26] was ultimately proved to be an economic handicap.[27] This rig required more crew to handle sails than a schooner or barquentine[28] rig. The competition with these rigs, as well as with steamships, marked the end of the down easters. "It can be said, therefore, that the American [full-rigged] ship ceased development about 1890, and shortly thereafter disappeared."[29]

European shipbuilders, however, with their advanced industrial base, continued to build iron and steel square-rigged ships for an additional thirty years.

Steel Four-Masted Barques

While the down easters represented the zenith of the American sailing ship era, the steel ships of the 1890's crowned the efforts of the European sailing ship industry. New production methods made relatively inexpensive, high quality steel available to shipbuilders. This resulted in a marked increase in the number of large sailing ships built, particularly during the period of about 1888 to 1894.[30] Ships up to 3000 tons (gross tonnage) were constructed of steel, and a few ships of 5000 tons were built.

The most common rig was the four-masted barque.[31] These ships were built primarily for high cargo capacity and competed with the tramp steamers in the bulk trades.

The masts, yards, and much of the rigging were also steel.

Although speed was not a primary consideration in construction of the four-masted barque, the steel construction resulted in a particularly powerful rig that could withstand driving in strong winds. A competent master could therefore make excellent and consistent passages. This factor, coupled with the large cargo capacity of these vessels, resulted in an efficient bulk carriage system which was highly competitive with steam. Long ocean routes were especially suitable for sail, as fuel was not a consideration.

In spite of the increasing competition from steam ships, building of this successful steel sailing ship continued well into the twentieth century. The last British four-masted barque was launched as the Clyde in 1905.[32] The Germans built their last in 1926.[33] The French, who produced many fine ships of this rig, launched their last "bounty ships"[34] in 1902.[35]

Trade in which the four-masted barques became famous were Australian grain and Chilean nitrates. In either case, the voyages included at least one passage around Cape Horn. The sturdiness of construction of these ships paid dividends there, as well as in passages in the "roaring forties."[36]

In 1927 the last square-rigged ship to load a nitrate cargo cleared Tocapilla,Chile.[37] The last "grain race"[38]

from Australia to Europe took place in 1939.[39] A few four-masted barques continued to operate after World War I, and in isolated cases, until 1957. In that year, the Pamir, en route from the River Plate to London with grain, went down with eighty men and cadets during a hurricane.

Seven of these vessels are still afloat in various parts of the world in diverse states of preservation.[40]

Five-Masted Square Riggers

These vessels, seven of which were built, represent the ultimate culmination of the evolutionary process of the square-rigged sailing ship. Of these seven, six were five-masted barques, one being fitted with an auxiliary engine. The first was built in 1890, the last in 1921.[41] The five-masters were essentially larger and improved successors of the four-masted barques, and were employed in similar trades.

The seventh vessel, often referred to as the greatest sailing ship ever built, was the five-masted full-rigged ship Preussen. She was built in 1902 by Johann C. Tecklenborg for the German shipowner F. Laeisz. Villers describes Preussen as "the undisputed queen, the last, most perfect, and most useful development" and "a gesture of defiance flung at the mechanical age."[42]

Preussen was built for the nitrate trade with a cargo capacity of 8000 tons. Incorporated in her design was the

sum of man's knowledge of square-rigged sailing ships. "She was an unusual sailing vessel, capable of keeping to her timetable almost as regularly as the cargo steamers of those days. She could maintain a speed of 16 to 17 knots for several hours at a time . . ."[43]

The Preussen sailed for eight years, until she collided with a steamer in the English Channel in 1910. The fault lay entirely with the steamer, but Preussen ran aground and was a total loss.

This great sailing ship may have seemed an anomaly in her day. Yet, her owner felt that there was work to be done by sailing ships, and she was his proof.

Schooners

Schooners, like the down easters discussed above, were truly an American development. Although the rig was known to exist in Europe, it appeared in New England early in the eighteenth century, and by 1790 "the schooner had become the national rig of the United States and Canada."[44]

The fore and aft rig of the schooner is ideally suited to coastal trades because of its ease of handling and ability to sail to windward. America's seaboard development depended upon the coastal trading vessels, as the internal road system was poor. The schooner was ideal for this trade, which included cargoes such as grain, lumber, coal,

cotton, and bricks.[45]

In its early development the schooner rig had two masts. Then, about 1850 a need for larger vessels evolved, and three-masted schooners were built. They almost monopolized the coastal trades after the Civil War.[46] In 1880, the same economic factors which resulted in the three-master brought about the four-masted schooners. The first five-masted schooner was built for the Great Lakes trade in 1881.[47] Six-masted schooners were built after 1900 to compete with the early barge lines in the coal trade.[48] Only one seven-masted schooner, the Thomas W. Lawson, was ever built. She was difficult to handle and not a success.

> From the technical point of view, the remarkably long existence of the rig and certain hull-forms in commercial work proves the efficiency with which the schooner met economic and natural requirements. The advantages of the schooners over the square-riggers rested in the smaller crews required by the former, as well as the schooner's great handiness and surety in working in narrow channels and confined waters. There were disadvantages to the rig, particularly in very large vessels, but the relative importance of these can be gaged by the fact that the number of schooners rapidly increased at a time when other types of sailing craft were disappearing with great rapidity. The spread of the schooner's popularity was very remarkable. Beginning as an almost local type and rig, the schooner gradually became popular along the Atlantic seaboard to Canada, then in Europe and in Central and South America, finally in the Pacific and Far East.[49]

The historical success of this rig obviates its suitability as an ideal departure point for testing modern sailing ships.

THE DEMISE OF SAIL

The end of the great age of sail cannot be identified with a specific date; it took place gradually over a long period. In 1833, the Royal William made history by being the first merchant vessel to cross the Atlantic under steam power alone. Perhaps this was the first indication that steam would ultimately bring about the demise of the sailing ship. Regardless of this accomplishment, sailing ships held reign over the merchant shipping business for many succeeding years. It was not until 1885 that British seaborne trade tonnage carried by steamships exceeded the tonnage carried under sail. In that year steam accounted for 3,973,483 tons while sail accounted for 3,346,625 tons.[50] By 1890, during which year British shipping trade tonnage accounted for 48 percent of the world's total, the tonnage carried by steam almost tripled that carried by sailing ships.[51]

American ship building statistics also reflect the coming dominance of steam power. In fiscal year 1879 the gross tonnage of steam ships built exceeded that of sailing ships built for the first time, and remained ahead except for the two year period 1883-1884.[52]

By 1900, steam ships accounted for 63.9 percent of the world's ocean-carried trade, although their carrying power was 84 percent of world trade.[53] The steamship failed to reach its economic potential sooner because of the amount of shipboard space required for engines and coal. Additionally, long voyages or voyages where coaling and watering stations were not available could be attempted only by sailing ships, which relied only upon the power of the winds and currents. Voyages from Europe to Australia and back, a well-traveled trade route, actually resulted in a sailing ship's circumnavigation of the globe. The route was south through the Atlantic, then east around the Cape of Good Hope and through the westerlies to Australia. Return passage was made around Cape Horn via the westerlies, then north through the Atlantic. There was little opportunity for a steamer to replenish coal or fresh water on a voyage such as this. The first use of marine turbine machinery using an oil-fired boiler in 1907 signalled the beginning of the end of the bulky coal stowage problem.

The general worldwide trend toward mechanization at the turn of the century was obvious and well documented. However, some ship owners continued to make profitable use of sail; not through hard-headed resistance to steam ships or romantic notions, but through far-sighted beliefs that there was work for the sailing ship to do in ocean transport. One of the last significant uses of deep water merchant sail

was the nitrate trade between the west coast of South America and Europe from about 1875 until 1927. It was in this trade that the ultimate sailing ship development occurred in the building of the large capacity, powerfully constructed steel ships which could make consistent and profitable voyages. Two shipping companies are legendary in the nitrate trade - F. Laeisz of Germany and A.D. Bordes of France. The Laeisz firm built the five-masted full-rigged ship Preussen, discussed above. An investment such as that during this period certainly reflected a strong conviction that sail was a viable and economic means of transport. Alan Villiers laments that ". . . the Preussen could-and should-have founded an new sailing dynasty."[54] Perhaps this statement has become prophesy in light of the fact that Preussen has been used as a comparative model upon which performance calculations of Dynaship were based about 40 years after the destruction of the former. In 1926, still satisfied that sailing ships were economical, Laeisz built the four-masted bark Padua (now the Soviet training ship Kruzenshtern). This ship operated economically, solely under wind power, in a highly industrialized age, when, for instance, Henry Ford had just produced his 20 millionth mass-produced automobile, and most other sailing ships had disappeared from the seas.

Perhaps it was more of an attitude that drove sailing ships from the sea - an attitude that anything that was not

borne of the mechanical age had no merit. The argument most often cited is that sailing ships were not economical due to the abundant low cost fossil fuels available. Possibly the sailing ship just wasn't accepted into the mechanized and rigorously scheduled world of the Twentieth century.

Another oft cited reason for the demise of sail is that sailing ships required large crews to handle the increasing amount of sail on larger ships. This was perhaps more true of the clipper ship age than that of the steel bulk carriers of the late Nineteenth and early Twentieth centuries. Tea clippers were relatively fragile ships that were driven unceasingly in what may better be described as a gentlemen's game or race than a legitimate trade. A large crew was necessary to quickly reduce sail to prevent disaster in high winds. The large steel ships and barques could safely sail with smaller crews due to the increased strength and efficiency of the ship and rig. Preussen normally sailed with a crew of 44, which meant about 125 square meters of sail per man. In comparison, the clipper ship Great Republic had a sail area of 47 square meters per man,[55] and was less than half the size of Preussen. Villiers rounded Cape Horn in the full-rigged ship Grace Harwar with a crew of only 13 men on a passage that admittedly was not comfortable, but possible.[56]

Notwithstanding the above, modern labor saving devices available to builders of modern sailing ships eliminate the

need for larger crews. As shown in Chapter II, specifications for these ships call for crews no larger than those for comparably sized motor ships.

A reason with partial validity for the disappearance of sail power was that sailing ship's passage-times were not predictable. A method of transportation that relied solely upon the wind was subject to storms, lack of wind, and adverse winds, even though the ships sailed the routes that historically proved to be most favorable, such as the regions of the trade winds and westerlies. Finding the best winds in these regions became more scientific during the latter days of sail, and sailing times were improved.

Citing the records of the Laeisz Flying "P" Line again shows that their ships, through good design and management, made surprisingly consistent passages in the Chilean nitrate trade. Their 5-masted barque Potosi, during the period 1897 to 1914 made 15 passages from the English Channel to Valparaiso, Chile and averaged 67.7 days per passage.[57] Her fastest passage was 55 days and her slowest was 86 days. Seven of the 15 passages were between 62 and 69 days. Thirteen return passages from Iquique, Chile to the English Channel during the period 1895 to 1913 averaged 76.1 days, with the quickest being 57 days and the longest 87 days. Eight of the 13 passages took between 73 and 79 days, showing that her arrival times were consistent within one week's time on 62 percent of these passages.

The Preussen showed similar consistency in her passages.[58] During the period 1902 to 1905 she made seven passages from the English Channel to Iquique or Tocapilla, Chile, averaging 66.1 days per passage. Her best was 62 and her longest 78 days. Seven return passages from those two Chilean ports to the Channel averaged 74 days, with the range being 68 to 79 days.

Sailing ship arrival times were by no means as predictable as those of steamships. They were, however, on certain trades in the latter days of sail, a great deal less variable than has been inferred in the literature.

Sail technology, which was based on hundreds, even thousands of years of experience, was at its zenith when sail was replaced by steam. This situation is particularly significant and central to the argument for the reintroduction of wind powered ships. Steam propulsion was not encouraged because sail was failing as a mode of transport. To the contrary, sailing ships were continually improving. Steam was simply a different technology which proved itself superior by virtue of the difference. This new type of marine propulsion surpassed sail by reason of speed, maneuverability, and increase in potential ship size. The qualities of sail were never disproved, only challenged.

These observations are significant in that they counteract the seemingly perpetual notion of sail in romantic terms, when in fact, it is a profoundly practical method of

moving ships. Sailing ships were highly developed, efficient wind machines.

FOOTNOTES

[1]Douglas Phillips-Birt, _A History of Seamanship_ (New York, 1971), p. 23. Hereafter cited as Phillips-Birt, _A History of Seamanship_.

[2]Phillips-Birt, _A History of Seamanship_, p. 23.

[3]Phillips-Birt, _A History of Seamanship_, p. 31.

[4]Robert Wernick, _The Vikings_, Time/Life Seafarers Series, (Alexandria, Virginia, 1979), pp. 117-161.

[5]Phillips-Birt, _A History of Seamanship_, p. 22.

[6]Richard Humble, _The Explorers_, Time/Life Seafarers Series (Alexandria, Virginia, 1978), p. 51.

[7]Etienne Taillemite, "The Golden Age," _The Great Age of Sail_ (New York, 1967), p. 146.

[8]Etienne Taillemite, "The Golden Age," _The Great Age of Sail_ (New York, 1967), p. 159.

[9]Howard I. Chapelle, _The History of American Sailing Ships_ (New York, 1935), p. 284. Hereafter cited as Chapelle, _American Sailing Ships_.

[10]Sailing with the maximum sail area set, even during strong winds which threatened to damage the sails, spars, and rigging. This method of sailing, though rewarding for the master and owner, was extremely rigorous and hellish for the crew.

[11]Phillips-Birt, _A History of Seamanship_, p. 14.

[12]Alan Villiers, _The Way of a Ship_ (New York, 1970), p. 74. Hereafter cited as Villiers, _The Way of a Ship_.

[13]Villiers, _The Way of a Ship_, p. 76.

[14]Alan Stimson, "Wind and Weather," _The Visual Encyclopaedia of Nautical Terms Under Sail_ (New York, 1978).

[15]Villiers, _The Way of a Ship_, p. 60.

[16]Robert G. Albion, _Square Riggers on Schedule_ (Princeton, New Jersey, 1938), p. 20.

[17] Robert G. Albion, Square Riggers on Schedule (Princeton, 1938), p. 20.

[18] Robert G. Albion, The Rise on New York Port (1815-1860) (New York, 1939), p. 43.

[19] Carl G. Cutler, Five Hundred Sailing Records of American Built Ships (Hartford, 1952), p. 12.

[20] David R. MacGregor, Clipper Ships (Watford, Hertfordshire, 1979), p. 3.

[21] B.W. Bathe, "The Clipper's Day," The Great Age of Sail (New York, 1967), p. 207. Hereafter cited as Bathe, "The Clipper's Day."

[22] Basil Lubbock, The China Clippers (Glasgow, 1973), p. 92.

[23] Basil Lubbock, The China Clippers (Glasgow, 1973), p. 227.

[24] William Armstrong Fairburn, Merchant Sail (Lovell, Maine, 1955) II, 1582.

[25] Bathe, "The Clipper's Day," p. 227.

[26] A ship, or square-rigged ship is one with square sails on all masts.

[27] Chapelle, American Sailing Ships, p. 288.

[28] A barquentine is a vessel with three or more masts, square rigged on the foremast and fore-and-aft rigged on the remaining masts. A fore-and-aft rig has only one or two sails per mast, as opposed to five or six for a square rig. The manpower requirements for sail handling are therefore considerably less.

[29] Chapelle, American Sailing Ships, p. 288.

[30] Bathe, "The Clipper's Day," p. 241.

[31] A barque is square rigged on all masts except the aftermost mast, or jigger, which is rigged with a fore-and-aft sail.

[32] Bathe, "The Clipper's Day," p. 242.

[33] Basil Lubbock, The Nitrate Clippers (Glasgow, 1966), p. 104.

[34] These vessels were called bounty ships because of the building and mileage subsidies paid by the state.

[35] Alan Villiers and Henri Picard, The Bounty Ships of France (New York, 1972), pp. 71-236.

[36] The wind belt encircling the globe in the Southern Hemisphere (about 40° to 50° S.) where the prevailing westerly winds often blow with great fury.

[37] Basil Lubbock, The Nitrate Clippers (Glasgow, 1966), p. 144.

[38] A grain race was an informal tally of days underway, port to port, for all ships sailing from Australia to Europe in a given year. It was not a race in which all ships departed together, as departure dates could vary by months. Rarely did any of the participating ships sight one another during their passage.

[39] George Kahre, The Last Tall Ships (Greenwich, 1978), p. 170.

[40] Existing four-masted barques:

Name	Status	Location
Falls of Clyde	Museum Ship	Honolulu
Moshulu	Restaurant	Philadelphia
Padua	Soviet Training Ship Kruzenshtern	
Passat	Museum Ship	Travemunde, Germany
Peking	Museum Ship	New York
Pommern	Museum Ship	Mariehamn, Aland Islands
Viking	Museum Ship	Gothenburg, Sweden

[41] David R. MacGregor, Square Rigged Sailing Ships (Watford, Hertfordshire, 1977), pp. 99-100.

[42] Villiers, The Way of a Ship, p. 5.

[43] Captain Helmut Grubbe, "The Preussen," The Great Age of Sail (New York, 1967), p. 256.

[44] Paul C. Morris, American Sailing Coasters of The North Atlantic (Chardon, Ohio, 1973), p. 3.

[45] Bathe, "The Clipper's Day," p. 223.

[46] Chapelle, American Sailing Ships, p. 259.

[47] Bathe, "The Clipper's Day," p. 225.

[48] Chapelle, American Sailing Ships, p. 270.

[49] Chapelle, American Sailing Ships, p. 220.

[50] Christopher Lloyd, Atlas of Maritime History (New York, 1975), p. 89. Hereafter cited as Lloyd, Atlas of Maritime History.

[51] Lloyd, Atlas of Maritime History, p. 89.

[52] William Armstrong Fairburn, Merchant Sail (Lovell, Maine, 1955), II, 1575.

[53] Lloyd, Atlas of Maritime History, p. 89.

[54] Villiers, The Way of a Ship, p. 21.

[55] Fabian Acker, "The Winds of Change?" Chartered Mechanical Engineer, March, 1975, p. 94.

[56] Alan Villiers, By Way of Cape Horn (New York, 1930).

[57] Villiers, The Way of a Ship, p. 396.

[58] Villiers, The Way of a Ship, p. 397.

CHAPTER II

RECENT DEVELOPMENTS TOWARD MODERN WIND-POWERED CARGO SHIPS

The advocates of the reintroduction of wind power for modern commercial ships represent three distinct philosophies toward this goal. First, there are those who believe that modern sailing ships should evolve from the traditional state of the art of the early twentieth century. As shown in Chapter I, sailing ship technology was highly developed when replaced by steam power. The first three vessels discussed under traditional design have been operated or are about to be put into operation. These ships are Berta of Ibiza, John F. Leavitt, and Patricia A. Proposals for vessels following, for the most part, traditional design, are Windrose Ships, Ltd. International Sailiner, Warner and Hood schooner design, and a junk-rigged coastal trader.

Another group favors an approach which incorporates modern technological innovation into design of modern sailing ships. Many of these ideas introduce radically different modes of propulsion which have never been tested at sea. Ship proposals include Dynaship, University of Michigan designs, Carson sailing bulk carrier, Western Flyer project, Windmill ship, Wing sail ship, Flettner rotorship, the Trimaran "Small is Beautiful" and Ocean Arks.

Another group of modern sail advocates believes that initial efforts should concentrate on the development of auxiliary sail power. Existing motorships, already in operation and earning revenue, would serve as test platforms. The objective of auxiliary sails is to reduce fuel consumption, and thereby lower running costs at sea. Proposals for auxiliary sails include sails for auxiliary propulsion of a VLCC, Colin Mudie proposals, auxiliary sails for oil rigs, and a Japanese proposal.

CONCEPTS BASED UPON TRADITIONAL DESIGNS

There are scattered vestiges of traditional economic sailing operations throughout the world. This use of wind power is of local environic significance but is not considered here as a major influence in the development of modern sail. The following vessels, however, represent vital and significant advances in the reintroduction of wind propulsion for modern economic operations. The first three, the Berta of Ibiza, John F. Leavitt, and Patricia A have gone beyond the planning stages and have been built.

Berta of Ibiza

This vessel is a three-masted schooner which is not, in the strict sense, a modern ship. The Berta was built in 1945 in the Balearic Islands, Spain, and is typical of the coastal schooners which served the east coast of the U.S. through the 1930's. The trade in which she is engaged, however, is quite representative of that available to sailing ships today, whether they be traditionally rigged or built according to a more modern concept.

During July, 1978, Berta, captained by Jim Lewis, brought a cargo of antique furniture from Spain to New York and sold it at a "modest profit."[1] In November of that year Lewis contracted with Chesebrough-Ponds, Inc. for a 45-ton cargo from Brooklyn to Trinidad. Berta was ideal for this situation because of reported fire damage in Port of Spain, Trinidad which kept larger ships from off-loading at their traditional dock.[2]

Berta's length is 110 feet. Her tonnage is 162 gross, 117 net, and she can carry up to 150 tons of cargo.[3] She is owned by ten shareholders, including Lewis and several other crew members.

Berta's employment since her November, 1978 departure for Trinidad is unknown, and the author's attempts to contact Lewis or his associates have been fruitless.

John F. Leavitt

This schooner represents the most dramatic effort in the reintroduction of sail power in commercial shipping. The Leavitt was a two-masted schooner built and operated by Ned Ackerman of Thomaston, Maine. Unfortunately, this serious attempt to demonstrate sail power in modern trade ended tragically on December 28, 1979 when the vessel sank in the Atlantic about 300 miles east-southeast of New York City on its first working voyage. The schooner was carrying a load of lumber and tanning chemicals from Quincy, Massachusetts to Haiti.

Ackerman, inspired by the book "Wake of the Coasters," written by the vessel's namesake, worked for three years and spent an estimated half a million dollars[4] building the Leavitt. The vessel's length was 97 feet and her gross tonnage 98.4. She had a cargo capacity of 150 tons. Ackerman believed that a coasting schooner, relatively free of the maintenance problems which plagued those of the last days of working sail, could haul cargoes more cheaply than a motorized vessel of similar cargo capacity. He was attempting to substantiate his belief when the vessel sank. He had been contacted concerning several other cargoes, which shows that the market is, in fact, present. The premature demise of Ackerman's effort is most unfortunate.

Reasons for the loss of the Leavitt are not clear at

the time of this writing. The vessel itself appears to have been sound. Some felt that even though "Leavitt is overbuilt* for her 97 feet, no one faults the sturdiness or quality of her construction."[5] Crowley reports that the breed of vessel "has been proved from her keel to the tops of her trucks," but that her driver (Ackerman) has not.[6] Perhaps a lack of experience in seamanship was instrumental in the loss of the vessel. Sea conditions of 20 foot waves and 20 knot winds[7] hardly seem insufferable for a well constructed vessel of 97 feet.

The loss of the John F. Leavitt should not be considered a setback for modern attempts at commercial sail. The ship type has been proven historically. The cargoes appear to be abundant. The lesson to be learned, or perhaps relearned, is the sea holds dangers for any ship, and experienced seamanship is requisite for any attempt at operating modern wind-powered ships.

Patricia A

Mr. Hugh Lawrence, of Ocean Carriers Corporation, Sausalito, California is the promoter of the Western Flyer Project. This project involves the criteria selection and decision process in planning and building a 4500

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*Built with wooden hull members (frames, etc.) which are of larger dimension than necessary to meet standards for a vessel of that length.

DWT modern sailing vessel. This concept is further described on page 60.

As a test vessel for the more ambitious project, Lawrence has altered a German three-masted schooner which he has renamed Patricia A (Figure 3). The vessel is 170 feet in length and has a capacity for 450 tons of cargo and 6 passengers.[8] The vessel was modified in England (under the direction of J.B. Wynne of the University of Newcastle-Upon-Tyne) to include bipod masts. The sails will be supported by a wire rigged vertically between the peak of each bipod and the deck.

The vessel was first reported as planning initial operations in the summer of 1978. Apparent delays then resulted in an estimated October 1, 1979 sailing date. The latest prediction for completion of the ship's conversion is mid-April, 1980, when it will initiate cargo service between Miami and St. Kitts in the Caribbean.[9]

The three vessels discussed above have either been in operation, are presently operating, or will be in the near future. Those discussed below are proposed ships which stem from traditional design. In general arrangement and appearance, they appear as vessels that were in existence, in some cases, until the middle of the twentieth century. Modern technological advances were seized upon, however, where applicable, particularly in the areas of labor saving devices, crew accommodation, hull construction, and sails.

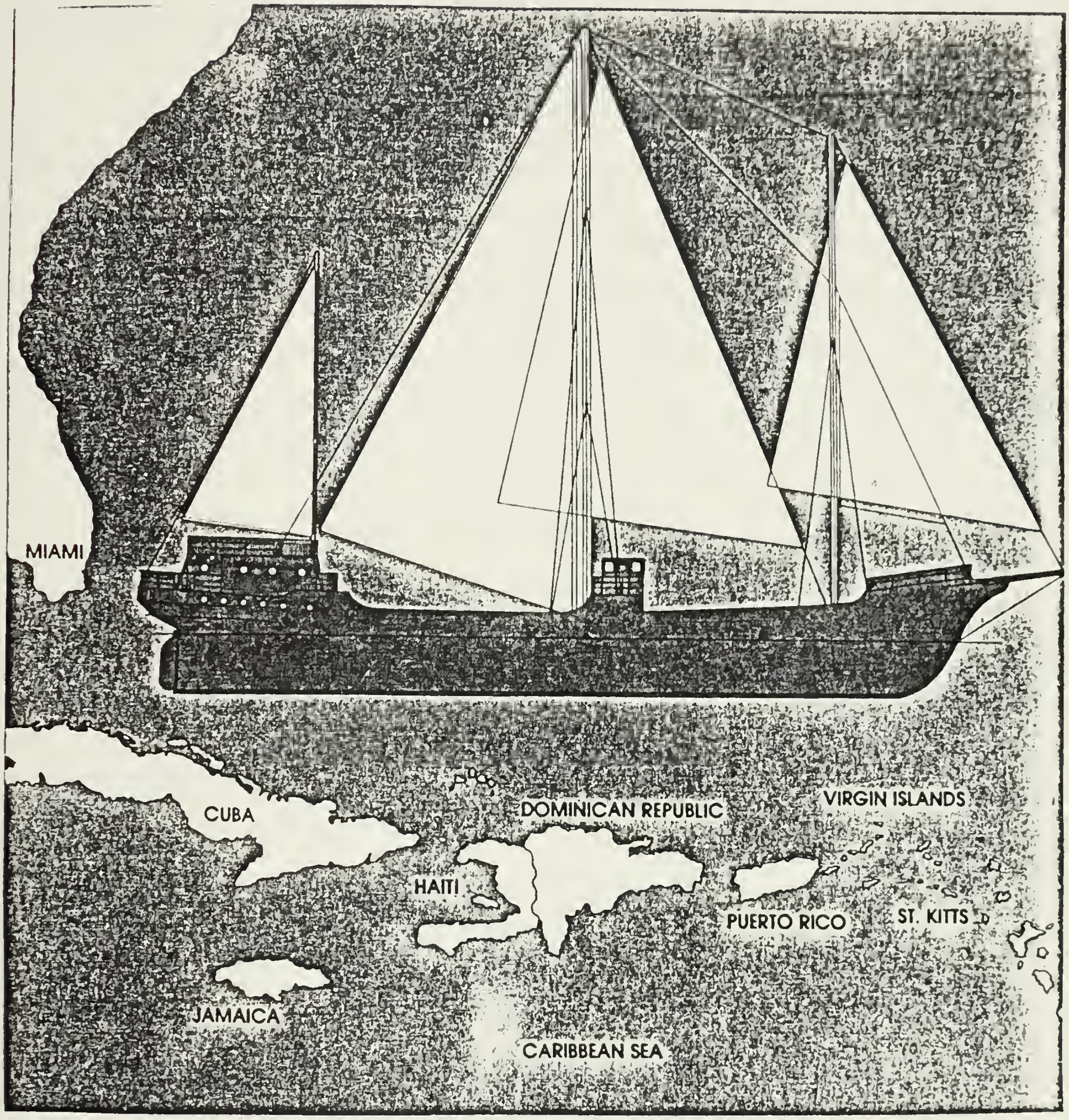

FIGURE 3. Patricia A
Source: Marine Engineering/Log, February, 1980, p. 51.

Windrose Ships, Ltd.

This firm has been set up in Fawley, Southampton "to provide comprehensive consulting service to shipowners interested in investigating the economics of the sailing ship."[10] Windrose has designed a modern version of an orthodox square-rigged sailing vessel called the International Sailiner. The firm does not see any of the other "academic" proposals as practical at the present.[11]

The International Sailiner design is of the traditional five-masted barque rig (Figure 4). The vessel's size of 12,000 DWT however, is about double the size of similar ships built in the early 1900's. Improvements in rig have been made which incorporate several labor-saving devices. These include hydraulic winches for hoisting and bracing yards, and hydraulically operated anchor windlass, steering gear, and docking winches. Auxiliary power will also provide domestic services for habitability comparable to those of modern motorships.

Two V8 diesel engines will provide sufficient power to drive the vessel at 11 knots when the winds are insufficient or adverse. A bow thruster has been included in the design to improve maneuverability in port.

The designers have made economic comparisons between the Sailiner and three motorships, and have concluded that the former is considerably cheaper to operate. These results are discussed in more detail on page 99.

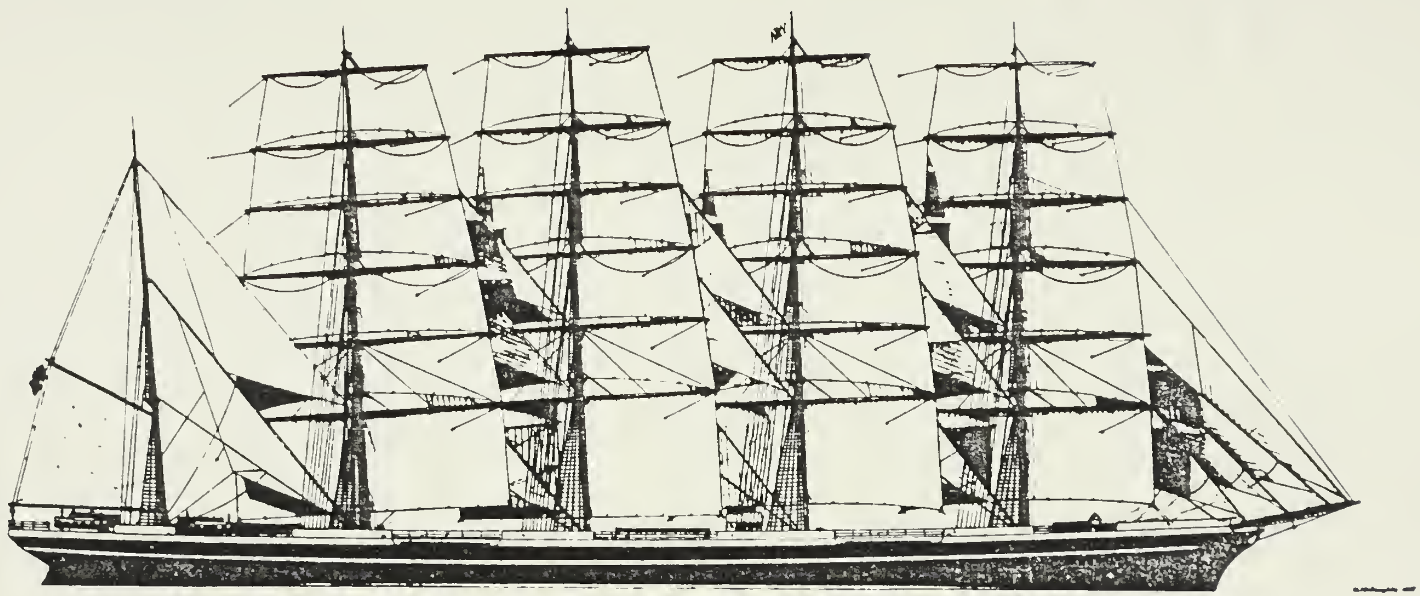

FIGURE 4. International Sailiner
Source: Windrose Ships Limited, International Sailiner Brochure, undated.

Windrose envisions the Sailiner sailed by a crew of 51, or as a combination cargo and training ship, by a crew of 86, including 60 cadets.

The company has presented the proposal to the UK government and has received a £5000 grant to produce a feasibility study on use of the vessel in a commercial training service. The study was then presented to the UK Department of Industry with a further request for finances for a complete design study including wind tunnel and tank testing. This request was rejected.

Windrose is now reportedly negotiating with a U.S. company to move their operations to New York.[12] Finding a financial backer among the conservative shipowner community is apparently proving difficult.

Warner and Hood Design

P.R. Warner, of Warner Pacific Lines, and Warwick J. Hood, Naval Architect, have designed a vessel for commercial/training operations in the South West Pacific Ocean.[13] They foresee the vessel's employment in the trade of bulk commodities such as bagged flour, bagged cement, and lumber on routes between Australia, New Zealand, Fiji, Tonga, and Samoa. The prevailing winds on most of these routes are very reliable and favorable for operations of a sailing vessel.

The initial drawings are for a four-masted schooner

of about 250 feet in length and 42 feet in beam (Figure 5). The vessel will have three cargo holds with a combined capacity of 2200 tons. The designers have included several technological advances in their proposal for this vessel. A double bottom for water ballast will allow an ample ballast capacity to ensure stability in an unloaded condition. Sails made of modern synthetic fabrics will be aerodynamically efficient and able to withstand the rigors of hard ocean-going commercial use. The designers anticipate that these sails will be twice as effective in producing a driving force as would cotton sails on a similar vessel. Another important technological advance intended is the smoothness of the underwater hull. The objectives are to obtain initially a low coefficient of friction for the hull and to discourage bottom fouling over time. These objectives are to be obtained by constructing a smooth welded hull and applying a high-performance antifouling paint. Warner and Hood anticipate a 25 percent decrease in the total hull resistance compared to traditional hulls.

Additional advantages resulting from the use of modern materials and construction methods will be a reduction in the weight of hull, masts, and rigging, and improved aerodynamics resulting from the use of smaller sizes of rigging. The installations of a facsimile weather chart machine and an electronic navigation device are also

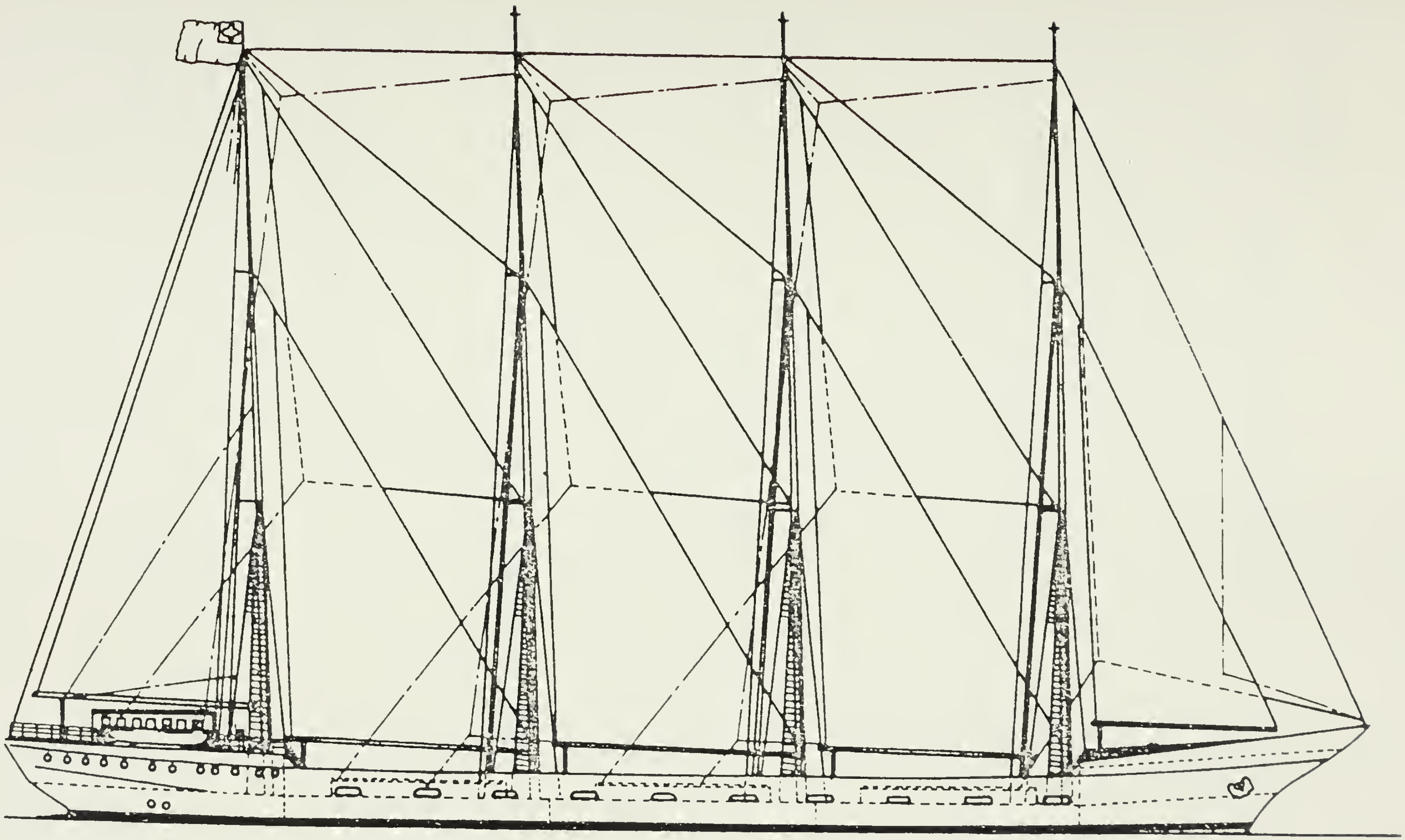

FIGURE 5. Warner/Hood Design
Source: P.R. Warner and W.J. Hood, "A Commercial Sailing Ship for the South West Pacific Ocean," The Royal Institution of Naval Architects, Occasional Publication No. 2, <u>The Future of Commercial Sail</u>, November 27, 1975, p. 44.

intended.

The vessel's design incorporates a small engine and a bow thruster. When compared to a similar sized motor vessel, predictions show a savings in fuel cost of $10,326 for a 5360 mile voyage on the routes mentioned above.[14] This comparison is based on fuel cost of $126 per ton in 1974. At the October, 1979 price of $180 per ton, the savings would be over $14,000.

The ship will be manned by five officers and a crew of 17, including 14 cadets. The designers see great value in the training of capable deck officers in order to assist the Pacific islands in advancing their status as maritime nations. This system will also help to lower the total wage cost of the ship.

The status of the Warner and Hood proposal beyond the planning stage is not known at the time of writing.

Junk-rigged Coastal Trader

H.G. Hasler, in the Journal of Navigation, has proposed a Chinese junk rig for relatively small coastal trading vessels or fishing boats[15] (Figure 6). The value of this type of rig, he explains, is its ease of handling by a small crew. In a vessel up to 50 feet in length, most sailing evolutions, such as tacking,[16] gybing,[17] reefing,[18] furling,[19] or making sail,[20] could be handled by a single

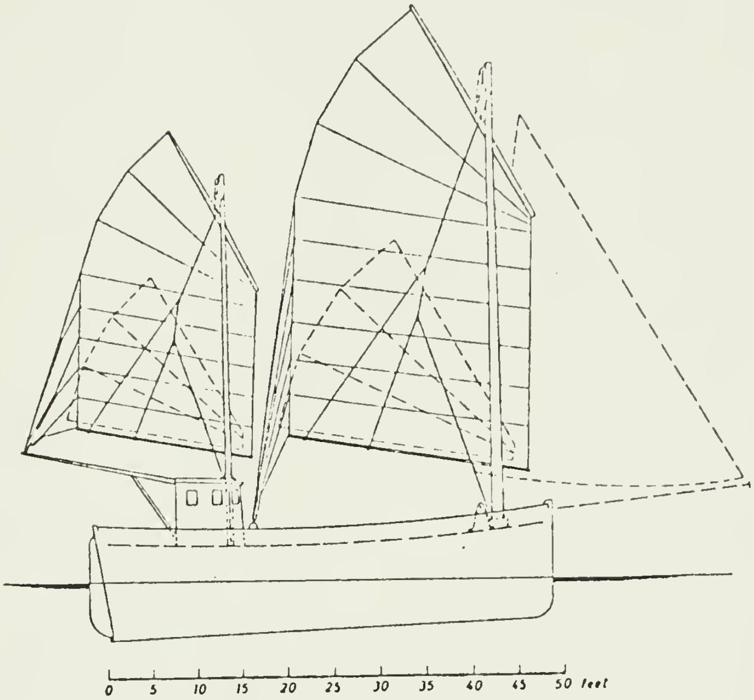

FIGURE 6. Junk - Rigged Coastal Trader
Source: <u>The Journal of Navigation</u>,
May, 1977, p. 202.

watchkeeper.

Hasler envisions the rig as practicable for vessels up to about 100 feet in length. In this case 70-foot masts would each support a single sail of about 2000 square feet. The sail would be of traditional junk design, with boom, yard and battens. This type of rig is self-maintaining during tacking or gybing evolutions. In case of unexpected heavy winds, the halyard[21] can be let go and the sail will quickly drop, gathering itself within its topping lifts.[22] The battened construction of the sail lends itself to easy reefing to any number of desired panels. The ease of handling the sails makes the rig ideal for a small crew, possibly a family crew. The uncluttered rig, including the unstayed masts, allow for exceptional working room on deck for cargo or fishing operations.

As in other countries, the junk sailing rig is inevitably becoming supplanted by the engine in areas of its traditional use. R.G.R. Worcester in his treatise on junks of the Yangtze, feared that his work was done too late and stated in 1967 that "Some of the finest types, as a result of the last few difficult years, have gone forever."[23] The author of this thesis was, in 1976, hard pressed to find a sailing junk under sail in Hong Kong harbor. Motorized junks are the rule. Perhaps the increase in fuel costs which have given rise to the proposals herein may also revive the traditional sailing junk. In

the case of this rig, the present generation should still retain the experience and expertise of sail, as the widespread transition to motorized propulsion was relatively recent. This is an advantage over the rest of the world which abandoned sail over a generation ago, and is rapidly losing the last vestiges of commercial sail experience.

TECHNOLOGICAL EXPLORATIONS

The stimulation of modern technology has stirred the creativity of the naval architect to a degree not even envisioned at the beginning of this century. At the end of the nineteenth century, it was the naval architect who stimulated others. Prior to this, railroad technology was the "cutting edge" of technological progress. Eventually, the thrust of shipbuilding was overtaken by the aircraft industry. Presently, space technology represents this cutting edge. The associated advances in electronics and computers have affected every field of technological endeavor.

The aircraft industry offers aerodynamic theory and practice never before available to the designer of wind powered ships. Relatively light, unstayed masts which support aerodynamically refined sails can be constructed of strong, metal alloys. The application of computers to both the design, construction, and operation of modern sailing ships is unprecedented. These technologies and

their refinements are represented in the following proposals for modern wind powered ships.

Dynaship

The Dynaship concept was developed in Germany in the mid-1950's by the German engineer Wilhelm Proelss. He envisioned a ship with up to six masts, basically square rigged, but modernized to include free standing tripod masts with sails and yardarms that form a continuous, cambered aerofoil from the bottom of the mast to the top (Figure 7). The sails or entire masts would be rotated hydraulically from the deck to obtain the proper sail angle with regard to the wind. Sail setting and furling would also be accomplished automatically by an operator on deck.

Proelss was supported by the Hamburg Research Council which sponsored extensive model testing of the rig at the Institute fuer Schiffbau of the University of Hamburg from 1961 to 1967. Comparative tests with a model of a conventionally rigged ship (a four-masted barque of the "Pamir" type) were made concurrently. Wagner studied the results of these tests and concluded that the Proelss sailing ship based on statistical wind data for the North Atlantic, would have a 56 to 58 percent higher average

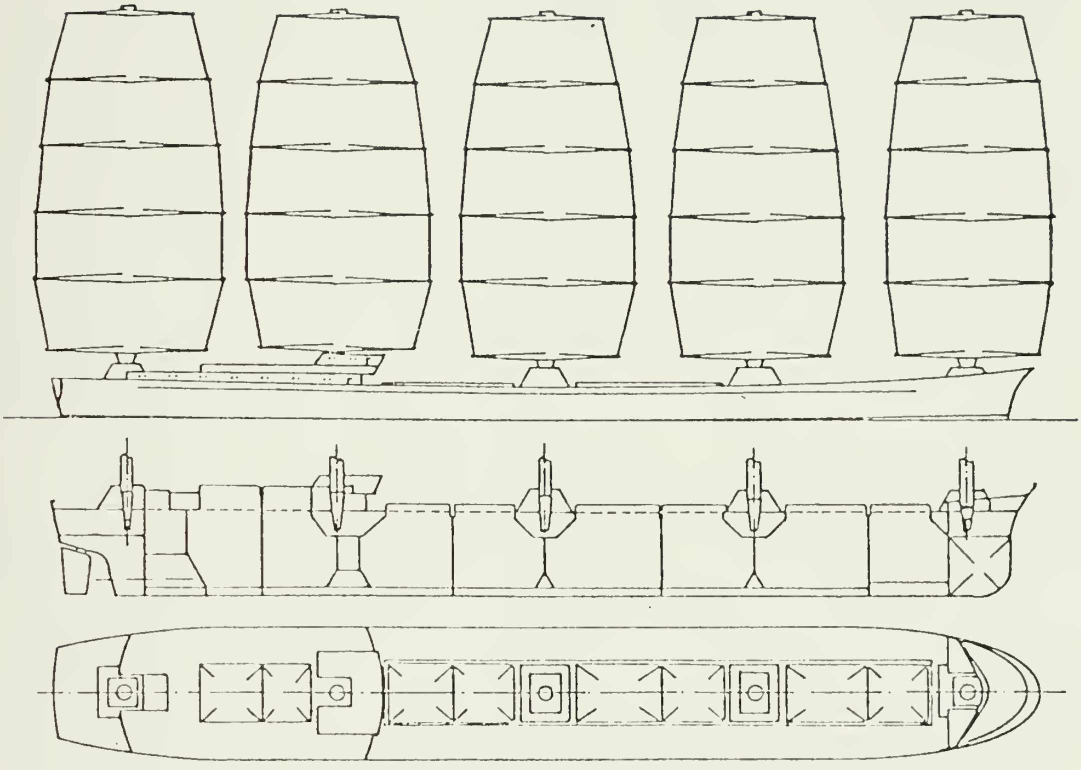

FIGURE 7. Dynaship
Source: William L. Warner and Miklos M. Kossa, "Updating an Ancient Art - Research and Development Toward Modern Wind Powered Cargo Ships," paper presented at Society of Naval Architects and Marine Engineers Symposium, San Francisco, May 25-27, 1977, p. 5.

speed* than the conventional sailing ship.[24]

In 1974, Dynaship Corporation of Palo Alto, California purchased exclusive rights to the Proelss concept for North and South America and the Pacific Basin countries. Danish interests hold similar rights for development in Europe. Prior to this transaction, Dynaship personnel tested a smaller version of the rig on Pumpkinseed and Shields' class sailboats. This convinced them that the rig was practical and performed according to predictions. The rig proved superior to a conventional sail on downwind courses, but was somewhat inferior close-hauled.[25]

Currently, Dynaship Corporation efforts are toward the development of computerized models to test the economics of the concept for various trade routes, ship sizes and cargoes, as well as development of specifications for the first vessel. President William Warner has ships' plans applicable to a vessel up to 45,000 DWT. Alternatives are to modify an existing motorship to accept the Dynaship rig or to demonstrate the applicability of the rig to fishing vessels. Warner has indicated through personal communication with the author[26] that Dynaship would be well suited to the time charter[27] market in the Pacific,

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*This increase is for a vessel without an auxiliary engine. If an auxiliary engine was installed, the resulting increase in speed would be 69-82 percent with the engine used between 14-25 percent of the time.

such as carrying canned pineapple from Mindanao, Philippines to the west coast of the U.S. Spot trading[28] in the Caribbean also offers opportunities.

Present Dynaship designs include single free-standing hollow masts with elliptical cross sections with low drag characteristics.[29] The spars are of fixed curvature, and firmly hold the head and foot of each sail in inset tracks. Sail furling is accomplished automatically by sail furling rollers inside the masts. The sails are therefore stowed inside the mast, protected from the elements when not in use.

Dynaship average port-to-port speeds have been predicted at 10 to 12 knots, assuming that the auxiliary engine, which will drive the vessel at eight knots, will operate 15 percent of the time.[30]

The Dynaship design represents the most advanced and extensively researched modern sailing ship proposed to date. Even though the initial building cost is about the same for that of a similarly sized motor ship,[31] no shipping company has yet contracted to build one. Dynaship Corporation claims their vessel will consume up to 90 percent less fuel than a motorized ship, which can result in a $10,000,000 savings over a ship's life.[32] A greater cargo capacity results from the lack of a main propulsion plant and its fuel. Manning levels are predicted to be approximately equal to those for motor ships of the same

size (21 for a ship of 14,000 DWT).

In summary, the Corporation states that: "Dynaships, when compared with conventional ships, offer lower operating costs plus greater cargo capacity for the same investment. In spite of slightly lower average sea speeds, Dynaships yield a substantially higher return on invested capital and/or more competitive freight rates."[33]

The corporation is set up to supply masts, sails, related control systems, marine engineering services, crew training, sail maintenance and weather routing to a customer. The technology exists and the economic benefits appear to have been predicted to a high degree. A prospective shipowner with an eye to the future is required to put the first Dynaship in ocean going trade.

University of Michigan Design

In 1975, the Department of Naval Architecture and Marine Engineering of the University of Michigan produced a report sponsored by the U.S. Maritime Administration entitled "Feasibility of Sailing Ships for the American Merchant Marine." This report, and its recommendations, are discussed in detail on page 82. The study proposed hull and sail plans for three commercial bulk sailing carriers which are reviewed here.

The three ship designs selected for the study were of 15,000, 30,000 and 45,000 DWT (Figure 8). In general

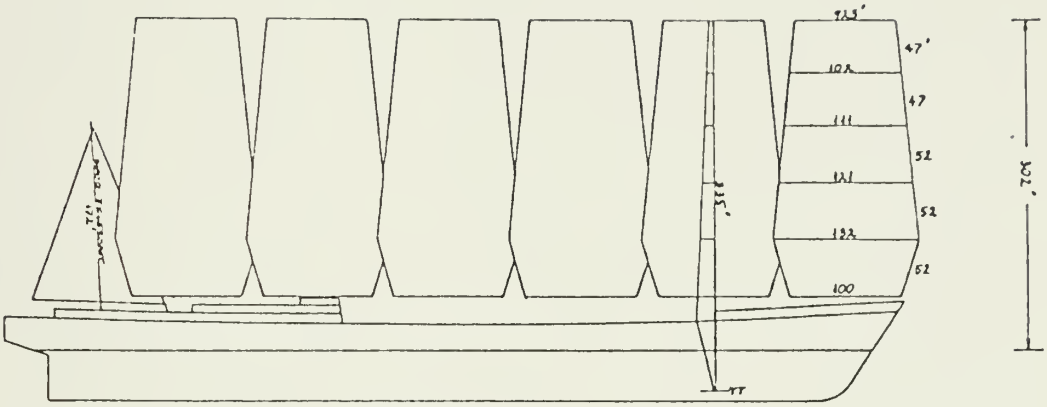

FIGURE 8. University of Michigan Design
Source: John B. Woodward, et al., "Feasibility of Sailing Ships For The American Merchant Marine," Department of Naval Architecture and Marine Engineering, University of Michigan, for the Maritime Administration of the U.S. Department of Commerce, No. 108, February, 1975, p. 20.

appearance, each is quite similar to the Dynaship design. The two smaller ships have six masts and the largest has seven masts. The sails on each mast form a continuous aerodynamic surface from top to bottom. The masts are open tripod structures but the entire mast will not rotate to accommodate sail trim. Instead, each yard and sail will be trimmed individually. "The individual activation of the yards allows for a limited amount of twist in the sail from masthead to foot, a favorable effect since the apparent* wind vector varies with height."[34] Each sail can be trimmed to its optimum angle with the wind. Sail trimming is accomplished by wire braces which lead from the yards into the mast, then down to the winches on deck. Sails would be furled in toward the mast, as in the Dynaship, but would not be enclosed inside the mast as in the latter design. A recommendation was included to install deicing gear on vital moving parts to facilitate sail handling in cold weather.

The study proposes crew sizes of from 26 to 30 for the three vessels, and the authors "cannot foresee any significant reductions in crew size compared to powered ships."[24]

These proposals are general designs only, presented in the report as a basis for the economic feasibility

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*The relative, or apparent wind is that wind rector experienced on a moving ship. It is a combination of true wind direction and speed and ship's course and speed.

studies therein.

Carson Sailing Bulk Carrier

A paper entitled "Sailing Bulk Carrier Design" was prepared by Jay Carson in November, 1976.[36] The paper considers preliminary hull design parameters of a series of square-rigged steel sailing vessels. Hull characteristics for six vessels, each of 16,500 DWT, are considered. The purpose of the study is to present the design characteristics of the six vessels as a data set to be used for later calculations of average sailing speed and trading economics.

The sail system chosen for the design consists of six masts very similarly configured to the Michigan study design. The main spar and struts of the mast are designed to withstand forces of a 50 knot wind when the ship is proceeding at an angle of 58° to the wind*.

The design includes an auxiliary diesel engine to propel the vessel during calm and adverse weather conditions. A bow thruster is suggested for use in docking operations and for assistance in tacking the vessel. Fuel capacity sufficient to provide endurance to cross the

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*This angle represents that at which maximum side forces are developed according to studies by Proelss.

Pacific under power is provided in the event that the sails could not be used.

Sail handling systems are proposed that would minimize size of crew. A manning schedule including nine officers and 24 crew is suggested and equated to that required for a similar conventional ship.

Western Flyer Project

Western Flyer is a sailing ship design proposed by Mr. Hugh Lawrence of Ocean Carriers Corporation of Sausalito, California. His immediate plans to operate a smaller vessel, Patricia A, based on this project, were discussed earlier on page 41.

Western Flyer is a proposal for a fore and aft rig on a hull modeled after a typical French four-masted barque, the "Fennia" ex "Champigny" (Figure 9). The unique design feature is that of bipod masts, as described for Patricia A on page 42. Lawrence puts great faith in the hull type that he has chosen, describing those ships as "magnificent cargo carrying machines."[37] He has reservations about the square rig, however, and has chosen that described above, assuming that "the lack of windward ability of the old square-riggers was one of their major operational defects."[38]

Lawrence's design requirements for the sail plan are 1) good windward performance, 2) ability to make rapid and drastic increases and decreases in sail area, 3) minimum

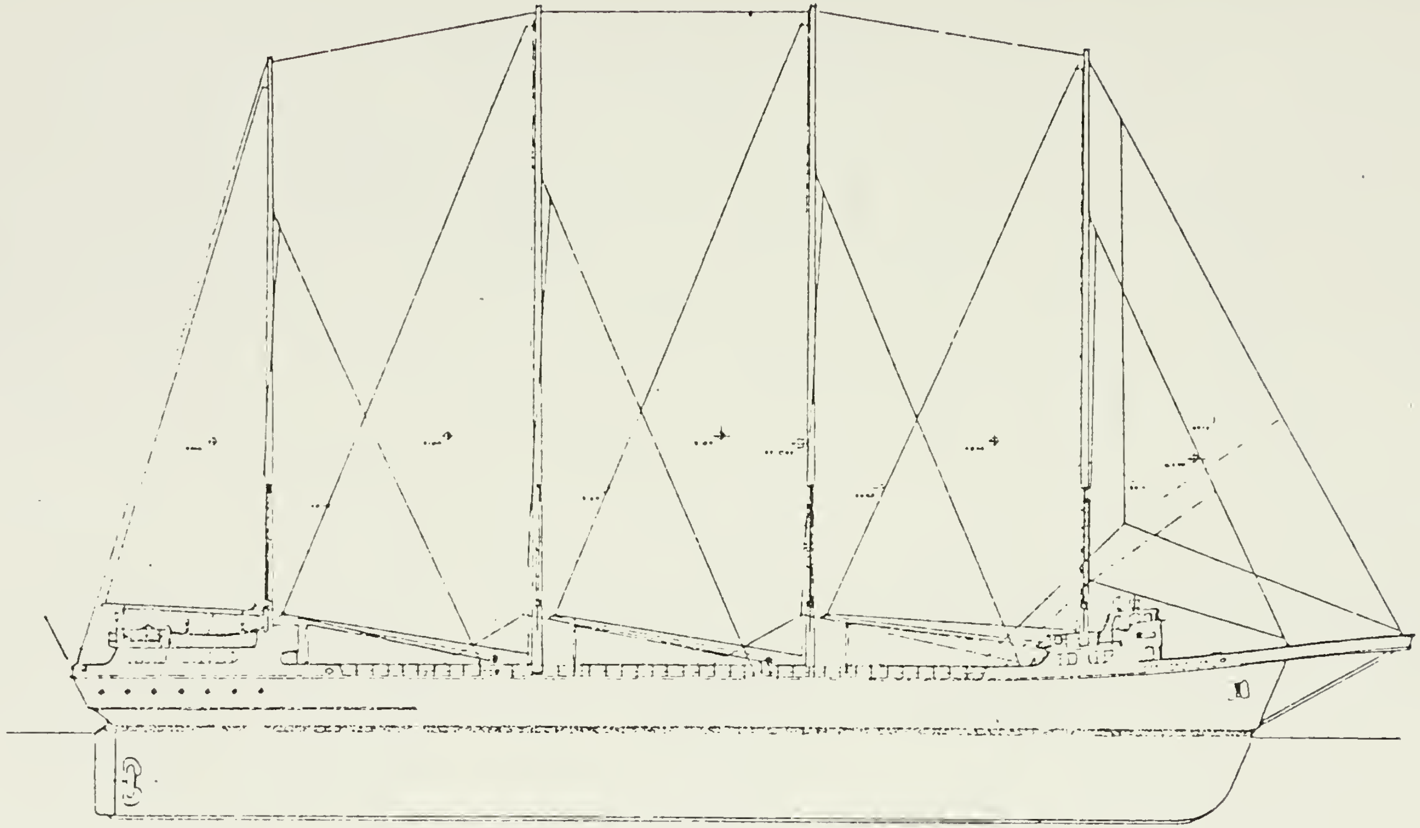

FIGURE 9. Western Flyer
Source: Hugh G. Lawrence, "A Modern Fore and Aft Rigged Sailing Cargo Ship," The Royal Institution of Naval Architects, Occasional Publication No. 2, <u>The Future of Commercial Sail</u>, November, 1975, p. 27.

novel features, 4) simplicity of gear, and 5) minimum weight aloft.[39] The use of bipod masts will eliminate the turbulance at the leading edge of the sail caused by a conventional mast. The sails will be supported on a wire rigged from the apex of the bipod to the deck. This wire also acts as the element around which the sail is furled.

The steel masts will be tubular structures 175 feet tall, each leg being 32 inches in diameter. Lawrence expects that the ship will conduct trade in small ports without efficient cargo handling gear. He is therefore investigating the possibility of integrating the masts into a cargo handling system. Ship's booms or cranes are also being investigated.

Lawrence expects the Western Flyer to require a crew of from 16 to 19, or no larger than that of a comparable motorship. Crews' quarters will meet the standards of those aboard motorships. Since all sail handling will be done by powered gear, there should be no requirement for the crew to go aloft at sea.

Voyage speeds for Western Flyer are based upon historical record. Lawrence anticipates the minimum effective voyage speed as 9.8 knots. This estimate is adjusted to reflect the use of auxiliary power as needed. It is not adjusted for anticipated advantages accruing from the use of real-time weather routing information. Lawrence explains that additional hull resistance informa-

tion is needed to refine this speed estimate.[40]

Navigation aids to be used are Loran, weather facsimile receivers, radar, and satellite navigation systems.[41]

Windmill Ship

John Wellicome, of the University of Southampton, has made an appraisal of a cargo ship propelled by a large windmill.[42] He chose a hull size of 21,000 tons displacement as a basis upon which to theorize on performance characteristics of a windmill ship (Figure 10), as well as Dynaship, a rigid wing sail, and Flettner rotors.

Wellicome envisions a four-bladed, variable pitch windmill rotor of 166 meters diameter driving a fixed pitch water propeller through an appropriate gear train. He admits that the size of the windmill is large, but Wellicome's calculations show that this is the size necessary to obtain the performance characteristics similar to the other rigs tested.

The most unique feature of the windmill is its ability to propel a vessel directly into the wind. According to Wellicome, the propeller thrust can exceed the windmill drag to achieve sufficient speed through the water. His calculations show that this rig will achieve 13 knots to windward in a 35 knot wind as compared to 5½ knots for Dynaship. Another advantage of the windmill is its elimination of the need to tack.

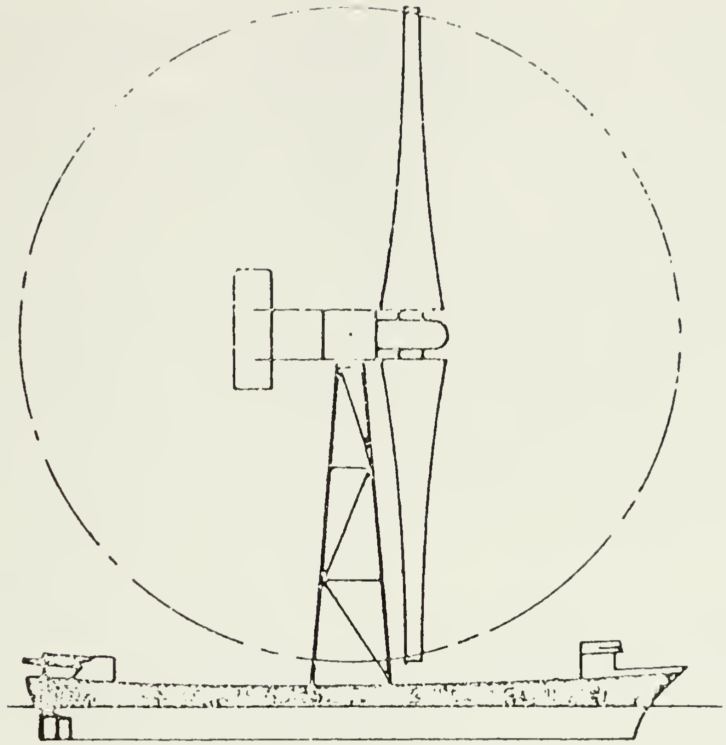

FIGURE 10. Windmill Ship

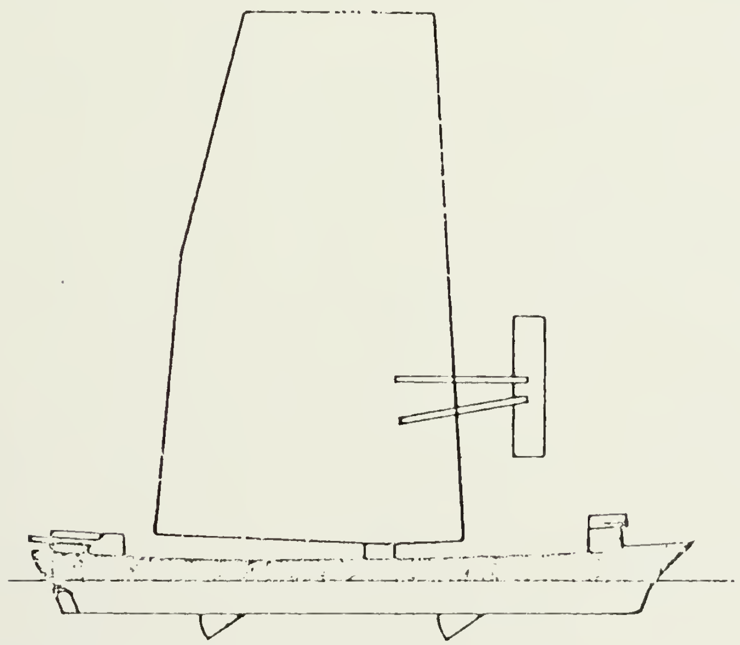

FIGURE 11. Wing Sail
Source: The Royal Institution of Naval Architects, Occasional Publication No. 2, The Future of Commercial Sail, November 27, 1975, p. 72.

This rig presents disadvantages for a vessel running before the wind. Wellicome anticipates two propulsion conditions, assuming that no alternative power is made available. One alternative is to stop the windmill and allow the water propeller to idle, accepting its drag. Another is to adjust the pitch of the windmill to a condition of high rotor drag wherein the propeller turns in a zero thrust condition. The rotor drag in this case provides the propulsive force.

This proposal presents a radical departure from traditional sailing ship operations. Here is a vessel driven by the wind which can sail directly into the wind. Conversely, the following winds so welcomed by square-rigger sailors for hundreds of years would be most discouraging for this vessel.

A major disadvantage of the windmill ship is the large rotor size, which would result in a restrictive "air draft" for the ship of over 550 feet. This compares to a mast height of approximately 200 feet for Dynaship. A ship with a windmill rig of this size would be restricted from ports with even the highest bridges. The Golden Gate, for instance, has a clearance of about 230 feet. The high gearbox and supporting structure weight aloft would present challenging stability problems. Further research concerning this concept must eliminate this problem in order to make the system feasible.

The windmill ship has, however, some unique and useful characteristics and should remain in the inventory of technologies to be considered in the future. Its combination with other rigs may offer benefits, particularly in regard to its windward ability. A modification of the Wellicome proposal placing the windmill structure well aft in order to shorten the shafting between the windmill and the propeller would also allow for an uncluttered cargo handling area.

Air Commodore C.T. Nance of Medina Yacht Co., Ltd., is reportedly studying a wind turbine propulsion system.[43] These turbines would rotate horizontally on vertical axes and would apparently not have the excessive air draft of a windmill. This study is receiving financial support from the U.K. Department of Industry's Ship and Marine Technology Requirements Board.

Wing Sails

The rigid wing sail is another progressive rig discussed by Wellicome.[44] The sail is similar to an airplane wing erected vertically on a ship's deck (Figurell). According to Wellicome, this rig would be advantageous over the Dynaship square rig, which loses efficiency in the multi-mast configuration due to wind interference between masts. According to Warner and Kossa, the rigid airfoil sail "represents the ultimate in efficient upwind

propulsion."[45] It does, however, have disadvantages. In order for the structure to have sufficient strength, a sail of this size would have to be constructed of metal. Wellicome estimates the rig weight at 850 tons, as compared to 370 tons for the total rig weight of Dynaship. Another drawback is that the rigid wing sail would need to be symmetric, so the ship could sail on both tacks. Therefore, the sail would "stall" at a comparatively modest angle of attack.[46] Wellicome describes a more complex wing sail that would overcome this problem. This "high lift" wing sail consists of three wing sections set nose to tail (Figure 12). The resulting airfoil could be adjusted to control the camber. A major disadvantage of the rigid wind sail is its lack of provision for reefing.

Warner and Kossa discuss a semi-rigid wing sail, the "Princeton Sailwing," which can partially eliminate the above disadvantages.[47] This sail is of fabric, with a rigid leading edge and upper end plate (gaff) and lower end plate (boom). The fabric sail "deforms" under aerodynamic loading to form a cambered airfoil shape, regardless of the side of the sail on which the wind impinges. Warner and Kossa admit that further testing is necessary, but the rig holds promise in combination with the Dynaship square-rig.

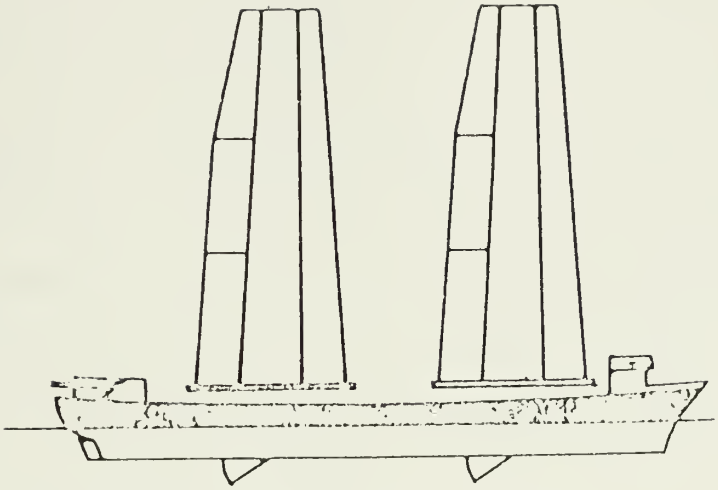

FIGURE 12. High Lift Wingsail

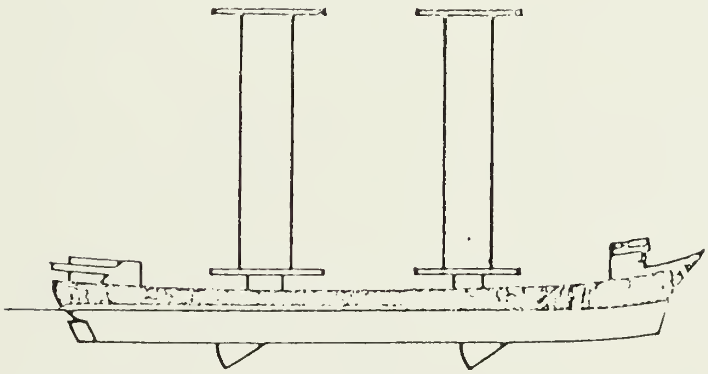

FIGURE 13. Flettner Rotorship
Source: The Royal Institution of Naval Architects, Occasional Publication No. 2, The Future of Commercial Sail, November 27, 1975, p. 72.

Flettner Rotorship

This form of ship propulsion is another discussed by Wellicome.[48] A Flettner rotor is a large, vertically mounted rotating cylinder which derives propulsive thrust from the development of lift and drag forces (Figure 13). This force generation is termed the "Magnus Effect."

In 1926 the rotorship "Barbara" was designed by Anton Flettner for the Transportation Department of the German Navy. She first sailed under charter as a fruit carrier.[49] The ship had three rotors, each 17 meters high and 4 meters in diameter. Another ship, the "Buckau," of 680 tons, had two rotors and made a transatlantic voyage, achieving speeds of 5-6 knots in a 10 knot wind.[50]

Wellicome describes this type of vessel as "wind assisted" rather than wind powered, because significant amounts of power are required to maintain cylinder rotation. This rotation then deflects the wind and produces lift. The auxiliary power required to turn the rotors and obtain a given speed is about a tenth of the power required to drive the ship at the same speed with a propeller.[51] Wellicome states that driving the ship at nine knots using rotors requires not more than three percent of the power required to drive a vessel conventionally at 23 knots.

When operating a rotorship before the wind, the lift generated by the rotor acts perpendicular to the ship's track and does not provide a propulsive force.[52] The

propulsive force is solely due to the force of the wind against the cylinder (induced drag coefficient).

Wellicome states in summary that the rotorship "can achieve respectable speeds through the water on most points of sailing."[53]

Small Is Beautiful

Multihull boat enthusiast Phil Weld, in cooperation with designers Dick Newick and Jim Brown, have introduced the trimaran "Small is Beautiful."[54] The concept is a reintroduction of multihull sailing and "soft" technology construction to Third World fishermen. The group also hopes the concept will stimulate native involvement in island tourist trade, as well as inter-island transportation.

This wind-powered trimaran is 31 feet in length and 22 feet in beam. It has been designed as a small fishing craft, and is in that sense quite different from the other proposals discussed above. Empty displacement is 2000 lbs., which will double when loaded to her one-ton cargo capacity. As a tourist boat, the vessel's capacity will be 11-15 persons. A 24-30 inch draft will allow the craft to be operated from the beach, an important consideration where docks and harbors are scarce or don't exist at all, and don't need to.

The vessel is a two-masted schooner with unstayed masts and no headsails. The uncluttered rig has few blocks and halyards, and does not require winches. Sail design allows for efficiency and ease of handling. The foresail is a two ply, double wing sail which is permanently affixed to the mast. When running before the wind the two halves are opened, to double the sail area. When sailing upwind, they lie against each other and act as a conventional sail. The sail is reefed or furled by rotating the mast.

The mainsail has a sleeve which fits over the mast. This eliminates a need for sail tracks and improves the aerodynamic efficiency of the sail. It is raised and lowered by a halyard.

The hulls are built of wood and are constructed using an epoxy saturation technique. This method does not require high pressure and heat and is within the capabilities of Third World individuals. Advanced skills and sophisticated machinery are not required.

The Peace Corps and World Bank have expressed interest in "Small is Beautiful."[55] The designers have responded with eight alternative designs to suit the needs of different types of fishing.

The Small is Beautiful concept demonstrates fundamental environic qualities not found in the proposals discussed earlier. The designers are bringing to Third World

fishermen and traders a vessel which will reawaken individual productivity and craftsmanship. A group of fishermen can cooperate in "backyard" boat construction. The finished vessels will not be dependent on expensive fuels. Many of the Third World archipelagos are favored by tradewinds or monsoons which offer a natural propulsive force for these craft.

Crowley relates Small is Beautiful designer Jim Brown's description of the vessel as flexible, "moving with the waves, instead of against them."[56] This quality will revitalize a fundamental relationship between ships and the sea, a quality lost in the large, impersonal vessels of today. The environic consciousness of this development is a fitting tribute to E.F. Schumacher, originator of the "Small is Beautiful" concept.

Ocean Arks

This innovative concept is the work of John Todd, president of Ocean Arks, Inc. of Falmouth, Massachusetts. Todd, disturbed by the global destruction of the earth's ecosystems, foresees these arks sailing with cargoes of living and growing plants and animals. "The first ocean ark will be an international transporter of live freshwater and marine fishes, molluscs, and other aquatic organisms."[57] The economics of the project would be based on the sale of plants and animals for agricultural uses. The possible

adverse ecological consequences of introducing species to a new area are beyond the scope of this thesis.

Todd's design is for a vessel 210 feet long and 43 feet in beam, with essentially a canoe shape (Figure 14). Draft will be 6 feet which will increase to 16 feet with centerboards lowered. The sailing rig consists of two stayless masts, the lower part of which are aerodynamically shaped cantilevered vertical wings. The rational behind the use of this vertical wing shape is not adequately discussed in the reference. Each mast supports a square sail with upper and lower yards and horizontal battens. A triangular topsail will be fitted above the squaresail. Auxiliary propulsion will be provided by two small tender boats to be stowed on deck while the vessel is under sail.

The solar aquaculture and greenhouse elements are paramount in the ship's design. These components will be structural components of the vessel, and will virtually fill the central portion of the ship. Todd intends to cover this part of the vessel with a strong clear material that will provide a greenhouse effect. Four 50,000 gallon aquaculture tanks will continually circulate sea water to maintain ideal growing conditions for the "cargo" of various organisms. Tree culture operations will take place on four tiers of racks built along the sides of the greenhouse canopy.

Todd intends to install modern navigation aids such

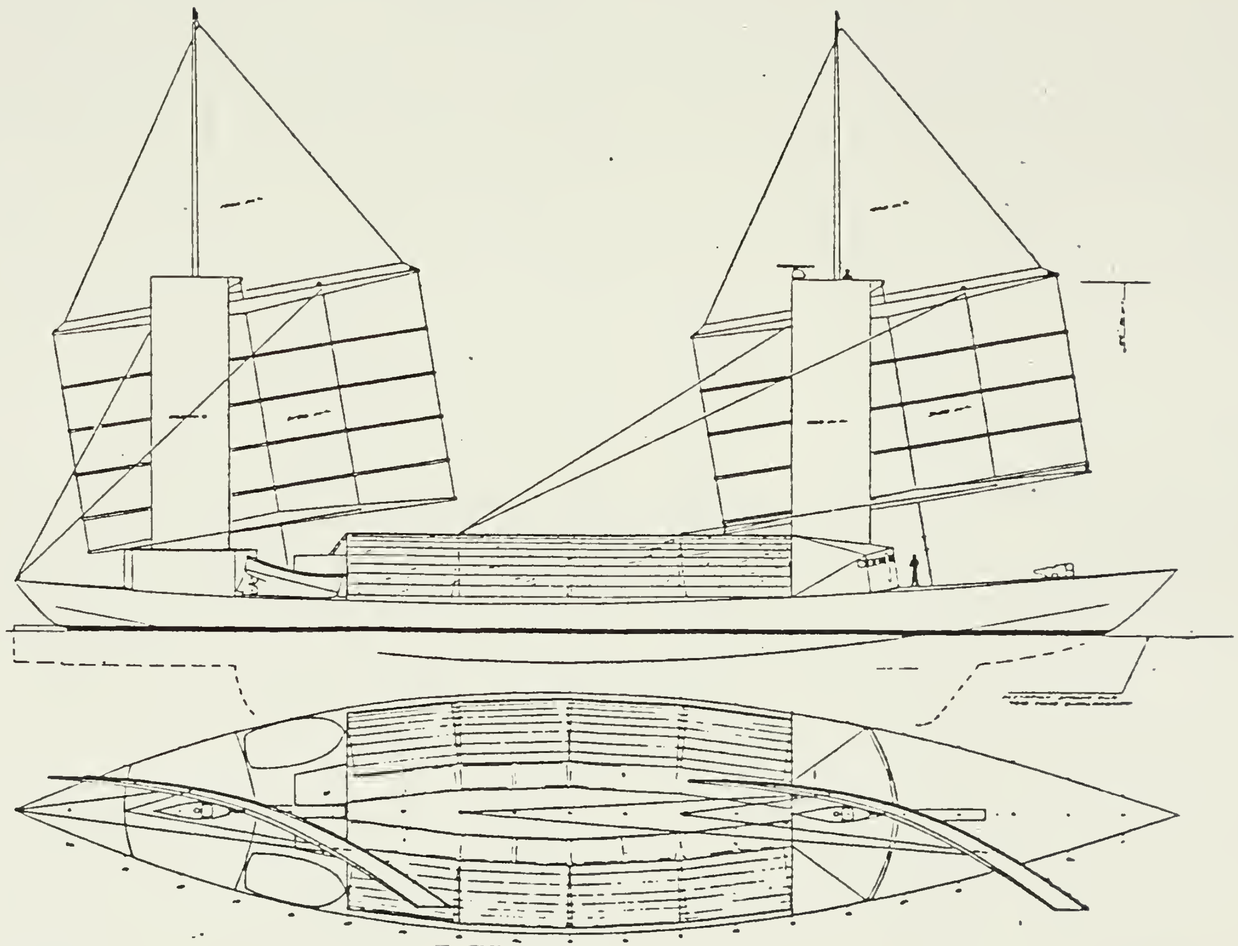

FIGURE 14. Ocean Ark
Source: Co-Evolution Quarterly, Fall, 1979, p. 52.

as satellite navigation, LORAN, radar, a computer, and appropriate communication equipment.[58] No mention is made, however, of the power source for this equipment.

The first ark is to be named "Margaret Mead," in honor of one who believed in the ecological, social and environic principles exemplified by the ocean ark concept.

In October, 1979, a 50-foot model of an Ocean Ark was built and sailed on Buzzard's Bay in order to test the hull and rig designs.[59]

SAIL AS AUXILIARY POWER

Hitherto, ships depending on wind power as the major propulsive force have been considered, but others also deserve serious consideration. One group of modern wind power enthusiasts proposes that sails be used on existing motorships as auxiliary power. When winds are favorable, sails would be used alone or in conjunction with reduced conventional power. When conditions are unfavorable, the sails would be furled and the vessel would proceed under engines. The objective is to reduce fuel consumption. No other cost reductions are anticipated, as no modifications in main propulsion machinery are expected. The cost of the sailing rig will, in fact, be an additonal expense which will ideally be compensated for by savings in fuel.

Sails for Auxiliary Propulsion of a VLCC

This proposal was introduced by J.B. Wynne, of the Department of Naval Architecture, University of Newcastle-upon-Tyne.[60] His proposal discusses the economics of operating a 220,000 DWT tanker (Very Large Crude Carrier) with auxiliary sails on the Northern Europe-Persian Gulf route. Although few details are included concerning the type of rig to be used, Wynne does propose a square-rig. He suggests a sail area of 18,000 square meters arranged on six masts, each 75 meters high. There is no mention made concerning lowering mechanisms for the mast, so presumably they remain standing even when the sails are furled. No discussion is presented concerning the resultant increase in drag when proceeding into the wind.

Wynne discusses the effect of the propeller when the vessel is under sail. A locked propeller would result in a speed penalty of up to two knots.[61] He states, however, that this would be greatly reduced if the propeller be allowed to trail.

Ship's heel would be minimal, according to Wynne, under usual sailing conditions. Even if the vessel was subject to crosswinds of approximately 35 knots, the angle of heel would be less than 10 degrees.[62]

Based upon the winds expected on the proposed route, the daily operating costs of the VLCC with and without sails, and cost of the sailing rig, Wynne concludes that

the auxiliary sails would not be economically feasible unless the price of fuel increased fourfold over the $80 per ton cost in 1975. He suggests, however, that more attractive results may be obtained if the cost of the auxiliary rig was lower or a route with a higher percentage of favorable winds was found.

In October, 1979, the price of Bunker C fuel oil was over $180 per ton.[63] In the near future, a fourfold increase in the 1975 price discussed above may not be an extravagant estimate.

Colin Mudie Proposals

A number of general proposals to reduce running costs at sea were presented by Colin Mudie, naval architect and yacht designer, in the Journal of Navigation.[64] Mudie's proposals are based on multiple wind power units of relatively small size. He addresses realistically the problems of sailing rigs during cargo handling operations, or during periods of non-use or repair. The units, he proposes, should be cheap, easily obtainable and maintainable, and available in several different sizes. They could be lowered, folded, or removed when not in use.

The units he proposes are shown in Figure 15. The Bermuda rig*, a modification of a modern yachting sail, is

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*A sail of triangular shape.

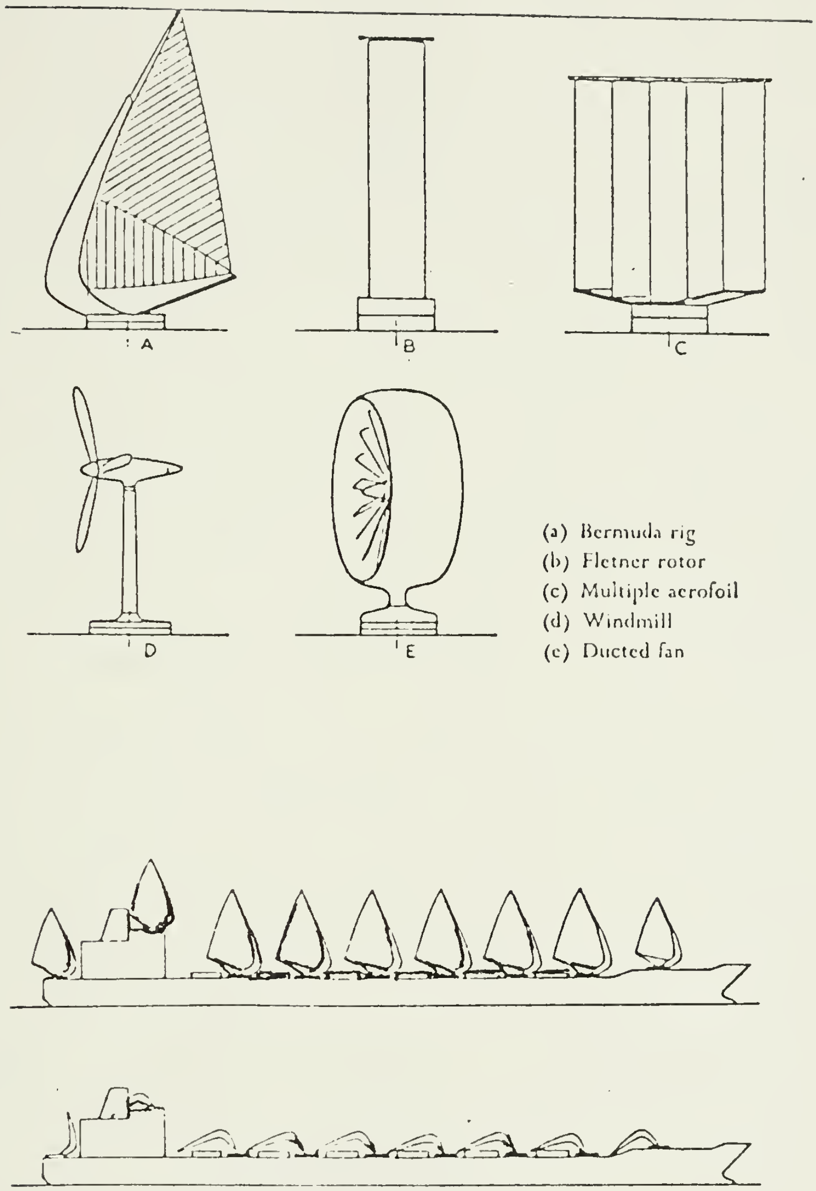

FIGURE 15. Colin Mudie Proposals
Source: The Journal of Navigation, May, 1977, p. 178.

apparently of Mudie's own design. It is an aesthetically pleasing rig. With twin booms and a double sail, its sail area could be doubled in following-wind conditions.[65] It could be mounted on a turntable and would meet the stowage requirements discussed above. He proposes that several of these units could be mounted on the deck of a ship such as a tanker or bulk carrier. Presumably he intends center-line mounting, but the sail area could be increased if the units were installed along each deck edge. This may also facilitate cargo handling from centered hatch openings. The other units shown in Figure 13 have been discussed under other concepts earlier in this thesis.

The above advantages of multiplicity of small units over a large rig are noteworthy, but may result in only 10 percent of the sail area of a larger rig. But, according to Mudie, the ship would operate under power at its normal economic speed, and would provide an essential relative wind, on certain courses, for the auxiliary sail units. This additional wind power would result in reduced fuel usage. He concludes that a 10 percent reduction in fuel costs would result.[66]

As in the preceding auxiliary proposal by Wynne, the economics of this method rely on fuel cost savings greater than the cost of the auxiliary rig.

Auxiliary Sails for Oil Rigs

The immense oil drilling platforms used by the off-shore oil industry are generally built ashore or in shallow waters, then towed to the drilling location. Auxiliary sails have been used on these rigs to reduce the towing time and fuel consumption. International Offshore Rig-1 (IOR-1) was rigged for sails manufactured by Ratsey and Lapthorn.[67] Costs of up to $25,000 per day can be experienced during towing operations. Speed increases of only one-half knot resulting from auxiliary sails can result in considerable savings, as some tows are transoceanic.[68]

The drilling rigs are floating platforms which will ultimately be raised and supported on legs reaching to the ocean floor. During towing, the legs are jacked up and extend up to 400 feet in height. IOR-1 was rigged with two triangular sails on the forward leg, allowing for use of both sails with a following wind. Each sail's area was 6,750 square feet.[69] The sails were each set on 203 foot by 8 inch extrusions, which were, in turn, supported by the leg of the drilling rig. These devices also acted as roller reefing gear for the sails.

During the first test the rig operated well, but evidence regarding speed increases was inconclusive due to speed recorder problems. Colin Ratsey is optimistic about the idea and "sees the day when all ocean-crossing rigs will carry auxiliary sails.[70]

Japanese Proposal

The Japanese shipbuilding firm Nippon Kokan is researching the use of auxiliary sails for bulk carriers, and possibly for tankers as well. Their test vehicle is the Daioh, a scale-model of a 460,000 DWT supertanker. The Daioh has actual dimensions of 26.3 meters in length and 4.55 meters in width.[71]

The objective of the test vehicle is to evaluate three different types of auxiliary sails.[72] The forward sail is a rectangular rigid sail, the dimensions of which are 4 meters by 7 meters. The second mast supports a fabric sail of the same dimensions. On the third mast, which is a lift-developing device with aerofoil cross-section, is a triangular fabric sail.

The firm estimates that a 20,000 DWT bulk carrier with a service speed of 15 knots would realize a 10 percent savings in propulsion power if the vessel is rigged with auxiliary sails.[73] A full-scale prototype may be approved for construction during the spring of 1980.

FEASIBILITY STUDIES

There are two major formally contracted studies concerning the feasibility of modern sailing cargo ships that extend beyond the scope of the studies mentioned above. Both of these have been sponsored by the Maritime Administration (MarAd) of the U.S. Department of Commerce. One was completed in February, 1975 by the Department of Naval Architecture and Marine Engineering of the University of Michigan. The project was headed by Professor John B. Woodward.[74] This report is referred to hereafter as the "Michigan Study." The other study is presently being undertaken by a group headed by Lloyd Bergeson, president of Wind Ship Development Corporation of Norwell, Massachusetts. MarAd selected this group after evaluating six proposals submitted in response to an August, 1979 request for proposals. The $138,840 contract was awarded on December 10, 1979.[75] The study is referred to hereafter as the "Bergeson Study."

The objective of both of the above studies is to determine the economic feasibility of wind powered ships for the American merchant marine.

Michigan Study

This study "was prompted by recent world developments in energy supply and environmental concerns" and "is an

economic comparison of the performances of several sizes of sailing ships versus those of comparable powered ships, all on several long trade routes from North American ports."[76] The ships were discussed earlier in this thesis (see page 56). The trade routes are Baltimore to Monrovia, New York to Liverpool, San Francisco to Sydney, and Seattle to Shanghai.

The report concluded that modern commercial sailing ships are technically feasible in size up to 50,000 DWT. Additionally, operational feasibility was predicted based upon criteria such as sailing routes and times, mast heights, heeling moments, crew size, auxiliary power, and cargo handling. The last phase of the study, that of economic feasibility, led to a conclusion that commercial sailing vessels are not an economically feasible alternative in the near future. However, the report does state that MarAd "should continue a modest effort to develop information showing how and where commercial sail may be used advantageously in the American merchant marine."[77]

Economic comparisons were conducted by route simulation by the three sizes of ships over the four routes. Speed estimates were based on computer simulation applying wind force and direction data from pilot charts to predetermined routes. The required freight rate (RFR) was used as a basis of comparison against similarly sized motor driven ships along the same routes. Of the twelve

ship/route combinations studied, sail was superior on one, and several others were close. The superior case was the smallest ship on the longest voyage, San Francisco to Sydney. This was surprisingly dismissed as inconclusive and "a reflection of the unsuitability of small ships in such service, rather than a valid sail vs. power comparison."[78] A further analysis of this economic feasibility study in light of current fuel prices is conducted on page 94.

This report has apparently been used as a basis for MarAd official policy, as reported by Lawrence.[79]

Bergeson Study

In the announcement of the award of the contract for this study, the Maritime Administration stated that "The group is to expand upon a preliminary study completed by the University of Michigan in 1975."[80] The increase in fuel prices, as well as the desire to reduce the nation's dependence upon foreign oil, are seen as motives for this followup.

The study "will analyze ship characteristics, trade routes, and commodities to determine market opportunities best suited for sailing ships of various sizes. It also will examine the overall economic potential of sailing ships in world trade."[81]

The statement of Work attachment to the Solicitation[82]

names four tasks to be considered. The intent of Task I is technological in nature and examines the influence that advanced technology offers modern sailing ships. Task II requires examination of commodities and trade routes. Task III calls for the development of an analytical model for assessment of various wind propulsion alternatives over different trade routes. Recommendations for further research are called for in Task IV.

As the study is now in progress, little further information can be gained regarding its direction. However, Lloyd Bergeson, the primary contractor, shed considerable light on his personal views regarding the subject of modern sail in a recent issue of Technology Review.[83] In that report Bergeson surmised that "rigorous analysis may well confirm that sail power has the potential to fulfill 50 percent - or even 75 percent, if need be - of all ocean transport requirements."[84] He sees a synthesis of traditional sailing ship technology and modern technology to develop modern ships. He is particularly partial to a modern fore-and-aft boomless staysail rig on improved hull forms, including multi-hulled vessels.

The final report of this study is expected in December, 1980.

FOOTNOTES

[1]Francis E. Bowker, "The Schooner Berta Puts to Sea," Sea History, Winter, 1979, p. 13.

[2]Stephanie Hollyman, "The Era of Wooden Ships and Iron Men (And Women) Returns," People Magazine, December 11, 1978, p. 64.

[3]Francis E. Bowker, "The Schooner Berta Puts to Sea," Sea History, Winter, 1979, p. 13.

[4]Jane Day, "The Return of Working Sail," Wooden Boat, November/December, 1979, p. 20.

[5]Jane Day, "The Return of Working Sail," Wooden Boat, November/December, 1979, p. 20.

[6]Michael Crowley, "New Schooner Tests the Waters for Carrying Cargo," National Fisherman, October, 1979, p. 81.

[7]South Bend Tribune, December 28, 1979.

[8]Hugh G. Lawrence, "Sailing Cargo Ships," Oceans, March-April, 1978, p. 58.

[9]Greg Ovechka, "Sail Cargo Ships to Arrive in 1980's?," Marine Engineering/Log, February, 1980, p. 50.

[10]Windrose Ships Limited, International Sailiner Brochure.

[11]Trevor Lones, "Getting the Wind Up Over Future Oil Supplies," Seatrade, December, 1978, p. 79.

[12]Trevor Lones, "Getting the Wind Up Over Future Oil Supplies," Seatrade, December, 1978, p. 81.

[13]P.R. Warner and W.J. Hood, "A Commercial Sailing Ship for the South West Pacific Ocean," Royal Institution of Naval Architects, Occasional Publication No. 2, The Future of Commercial Sail, 1976, pp. 29-46.

[14]P.R. Warner and W.J. Hood, "A Commercial Sailing Ship for the South West Pacific Ocean," Royal Institution of Naval Architects, Occasional Publication No. 2, The Future of Commercial Sail, 1976, p. 31.

[15]H.G. Hasler, "A Rig for Coastal Trades," The Journal of Navigation, May, 1977, pp. 200-203.

[16]Bringing a vessel's head through the eye of the wind so that the wind strikes the vessel's sails on the opposite side.

[17]Bringing a vessel's stern through the eye of the wind so that the wind strikes the vessel's sails on the opposite side.

[18]Reducing sail area by gathering up part of the sail and securing it.

[19]Rolling up a sail and securing it.

[20]Hoisting the sails for use.

[21]A line used to hoist a sail.

[22]A lift used for supporting the outer end of a boom.

[23]R.G.R. Worcester, Junks and Sampans of the Yangtze (Annapolis, 1971), p. xvii.

[24]B. Wagner, The Prediction of the Speed of Sailing Ships, Trans. H.C. Shaw, (Liverpool Polytechnic, 1975), p. 29.

[25]William L. Warner and Miklos M. Kossa, "Updating an Ancient Art - Research and Development Toward Modern Wind Powered Cargo Ships," paper presented at Society of Naval Architects and Marine Engineers Symposium, San Francisco, May 25-27, 1977, p. 5. Hereafter cited as Warner and Kossa, "Ancient Art."

[26]Dynaship Offices, Palo Alto, California, August 2, 1978.

[27]Time Charter: A contract between a shipowner and a shipper whereby the ship is chartered for an agreed time at an agreed rate.

[28]Spot Trading: A one-time employment of a ship whereby a cargo is transported to a given port for an agreed price.

[29]Dynaship Information Brochure, 1975, p. 3.

[30]Dynaship Information Brochure, 1975, p. 3.

[31]Warner and Kossa, "Ancient Art," p. 16.

[32]Dynaship Information Brochure, 1975, p. 7.

[33]Dynaship Information Brochure, 1975, p. 7.

[34]John B. Woodward, et al., "Feasibility of Sailing Ships for the American Merchant Marine," Department of Naval Architecture and Marine Engineering, University of Michigan, for the Maritime Administration of the U.S. Department of Commerce, No. 108, February, 1975, p. 21. Hereafter cited as Woodward, "Michigan Study."

[35]Woodward, "Michigan Study," p. 7.

[36]Jay Carson, "Sailing Bulk Carrier Design," paper presented to Society of Naval Architects and Marine Engineers, New England Section, November, 1976.

[37]Hugh G. Lawrence, "The Western Flyer Project - A Modern Sailing Cargo Ship," paper presented to Society of Naval Architects and Marine Engineers, San Francisco, September 9, 1979, p. 2. Hereafter cited as Lawrence, "The Western Flyer Project."

[38]Lawrence, "The Western Flyer Project," p. 7.

[39]Lawrence, "The Western Flyer Project," p. 7.

[40]Lawrence, "The Western Flyer Project," p. 25.

[41]Hugh G. Lawrence, "A Modern Fore-And-Aft Rigged Sailing Cargo Ship," Royal Institution of Naval Architects, Occasional Publication No. 2, The Future of Commercial Sail, 1976, p. 23.

[42]John Wellicome, "A Broad Appraisal of the Economic and Technical Requisites for a Wind Driven Merchant Vessel," Royal Institution of Naval Architects, Occasional Publication No. 2, The Future of Commercial Sail, 1976, pp. 57-80. Hereafter cited as Wellicome, "Broad Appraisal."

[43]R.F. Burnett, "The Viability of Commercial Sailing Ships - Areas for Research," The Naval Architect, September, 1979, p. 200.

[44]Wellicome, "Broad Appraisal," pp. 57-80.

[45]Warner and Kossa, "Ancient Art," p. 8.

[46]Wellicome, "Broad Appraisal," p. 65.

[47]Warner and Kossa, "Ancient Art," p. 8.

[48]Wellicome, "Broad Appraisal."

[49] M. Schelzel, "The Future," Ships' Cargo - Cargo Ships (Hounslow, England, 1979), p. 247.

[50] Wellicome, "Broad Appraisal," p. 67.

[51] Austin Farrar, "A Brief History of Sail and a Thought"to the Future," The Naval Architect, March, 1978, p. 58.

[52] Wellicome, "Broad Appraisal," p. 68.

[53] Wellicome, "Broad Appraisal," p. 68.

[54] Chris Cornell, "For Third World Fishermen - 'Small Is Beautiful!'," National Fisherman, April 30, 1979, pp. 58-60. Hereafter cited as Cornell, "For Third World Fishermen."

[55] Cornell, "For Third World Fishermen," p. 60.

[56] Cornell, "For Third World Fishermen," p. 60.

[57] John Todd, "Ocean Arks," The Co-Evolution Quarterly, Fall, 1979, p. 48.

[58] John Todd, "Ocean Arks," The Co-Evolution Quarterly, Fall, 1979, p. 54.

[59] J. Baldwin, "Trials of an Ocean Ark Model," The Co-Evolution Quarterly, Winter 1979/1980, pp. 56-59.

[60] J.B. Wynne, "Sails for the Auxiliary Propulsion of a VLCC Trading on the Northern Europe-Persian Gulf Route," Royal Institution of Naval Architects, Occasional Publication No. 2, The Future of Commercial Sail, 1976, pp. 47-56. Hereafter cited as Wynne, "Sails for the Auxiliary Propulsion of a VLCC."

[61] S.F. Hoerner, "Fluid Dynamic Drag," 1965, cited in J.B. Wynne, "Sails for the Auxiliary Propulsion of a VLCC," p. 50.

[62] Wynne, "Sails for the Auxiliary Propulsion of a VLCC," p. 50.

[63] Gene Heil, "Slow-Speed Marine Diesel Engines," Marine Engineering/Log, October, 1979, p. 47.

[64] Colin Mudie, "Reducing the Running Costs At Sea," The Journal of Navigation, May, 1977, pp. 172-180. Hereafter cited as Mudie, "Reducing the Running Costs at Sea."

[65]Mudie, "Reducing the Running Costs at Sea," p. 178.

[66]Mudie, "Reducing the Running Costs at Sea," p. 180.

[67]Mike Perry, "Rigged for Sail," Sail, p. 61-65. Hereafter cited as Perry, "Rigged for Sail."

[68]Perry, "Rigged for Sail," p. 62.

[69]R.F. Burnett, "The Viability of Commercial Sailing Ships - Areas for Research," The Naval Architect, September, 1979, p. 201.

[70]Perry, "Rigged for Sail," p. 65.

[71]Greg Ovechka, "Sail Cargo Ships to Arrive in 1980's?," Marine Engineering/Log, February, 1980, p. 52.

[72]News Review, The Naval Architect, September, 1979, p. 180.

[73]Greg Ovechka, "Sail Cargo Ships to Arrive in 1980's?," Marine Engineering/Log, February, 1980, p. 54.

[74]Woodward, "Michigan Study."

[75]U.S. Department of Commerce News Release, MA NR 79-8, December 10, 1979.

[76]Woodward, "Michigan Study," p. 1.

[77]Woodward, "Michigan Study," p. 11.

[78]Woodward, "Michigan Study," p. 8.

[79]Hugh G. Lawrence, "Sailing Cargo Ships," Oceans, March-April, 1978, p. 59.

[80]U.S. Department of Commerce News Release, MA NR 79-8, December 10, 1979.

[81]U.S. Department of Commerce News Release, MA NR 79-8, December 10, 1979.

[82]U.S. Maritime Administration, Statement of Work, Solicitation MA-79-SAC-00051, Attachment A.

[83]Lloyd Bergeson, "Sail Power for the World's Cargo Ships," Technology Review, March/April, 1979, pp. 23-36.

[84]Lloyd Bergeson, "Sail Power for the World's Cargo Ships," Technology Review, March/April, 1979, p. 24.

CHAPTER III

ECONOMIC AND LEGAL CONSIDERATIONS FOR MODERN SAILING SHIPS

When planning activities of any kind in today's cost and profit conscious society, the economic implications of the project appear to bear the most weight. Regardless of the merit of an activity in social, spiritual, natural, or aesthetic terms, it must be proven an economically sound argument or it simply won't proceed.

> In the current vocabulary of condemnation there are few words as final and conclusive as the word 'uneconomic'. If an activity has been branded as uneconomic, its right to existence is not merely questioned but energetically denied. Anything that is found to be an impediment to economic growth is a shameful thing, and if people cling to it, they are thought of as either saboteurs or fools.[1]

Use of the wind to propel ships across large expanses of water is a rational form of marine transportation. It represents an intelligent use of natural resources. Ships driven by the wind exhibit and confirm a fundamental relationship between man, wind, and water. Sailing ships have an aesthetic quality not to be denied. However, wind-powered ships will be required to show high profitability. Only then will they become a reality and be labeled economic, or "good," in their own right.

The legalities involved in the reintroduction of a form of transport that has lain dormant for 50 years are

apt to be quite complex. Paradoxically, all present regulatory criteria for ships and maritime trade have evolved from the days of sail, but their reapplication to modern wind-powered ships will be embroiled in entanglement. Regulatory bodies responsible for ship classification, licensing, operation and manning have been concerned with mechanically-powered ships for at least a generation, and a change of attitude may not come easily.

The following economic and legal implications have received only cursory attention in the literature concerning modern wind-powered cargo ships. In our complex society these aspects can be of equal or greater importance than the technicalities of designing and building a seaworthy ship. Advocates of these ships must "grease the ways" in this regard or even the most sophisticated and seaworthy ship may be launched in vain.

ECONOMIC CONSIDERATIONS

Regardless of the other attributes of modern wind-powered cargo ships, they must be shown to have a high probability of economic success. Mr. William Warner, President of Dynaship Corporation, has pronounced that "only economics will get a ship built."[2]

The most obvious economic advantage of wind power is the savings of fuel costs. This is the thrust of most of the proposals and articles advocating a return to that mode

of propulsion. Considering the rapid increase in the price of fuel, and the growing U.S. dependence on foreign oil, this is valid.

In addition to the economics of energy, there are other, more subtle considerations such as economy of scale, construction costs, cargo availability, and investment opportunities which effect the outlook on modern cargo ships.

Fuel Costs

The greatest single cost of operating a motor-driven vessel is that of fuel oil. Estimates in March, 1979 show that fuel costs average 20 to 30 percent of the total operating expense of a vessel.[3] This figure will rise and become increasingly significant as further rises in the cost of petroleum and petroleum products occur.

Since inception of research on this thesis, the price of oil has risen from $12.50 per barrel (yearly average, 1977, for Arabian light crude) to $21.50 (average OPEC price on December 7, 1979).[4] Spot market prices as of December, 1979 have exceeded $50 per barrel. Domestic oil prices have increased from $8.57 per barrel in 1977 to $13.22 per barrel in 1979.[5] The 1977 average retail price for No. 6 Residual Fuel Oil,[6] used in ship's bunkers, was $13.23 per barrel. By December, 1979, this had risen to $24.44 per barrel.[7] Likewise, diesel fuel increased in

cost from $128 per metric ton (early 1979) to $290 per metric ton (October, 1979).[8] No relief in the continued upward spiral of fuel prices, including those of marine fuels, is apparent.

Most proposals for modern wind-powered ships discussed in Chapter II emphasize lower fuel costs as the central argument. The following discussion centers on the methodology of these arguments and reexamines them in the light of present and predicted fuel costs.

The Michigan Study, discussed on pages 82 to 84 compared the economics of similar sized steamships and sailing ships over various trade routes. The comparison used to test the viability of sailing ships was that of required freight rate (RFR) for each case. The study used a fuel price of $11.25 per barrel.[9] As discussed earlier, this resulted in the sailing ship being superior on only one ship/route combination. Lawrence argued that in 1977, average fuel prices of $13.25 resulted in six of the twelve ship/route combinations showing economic superiority.[10] Reexamination of all twelve combinations today at the December, 1979 price of $24.44 per barrel[11] show that sailing ships show economic superiority on each. This is demonstrated in figures 16 through 19, which are extracted from the Michigan Study and updated according to present fuel costs. In view of the above, the results of this study are strikingly different from the conclusions presented therein.

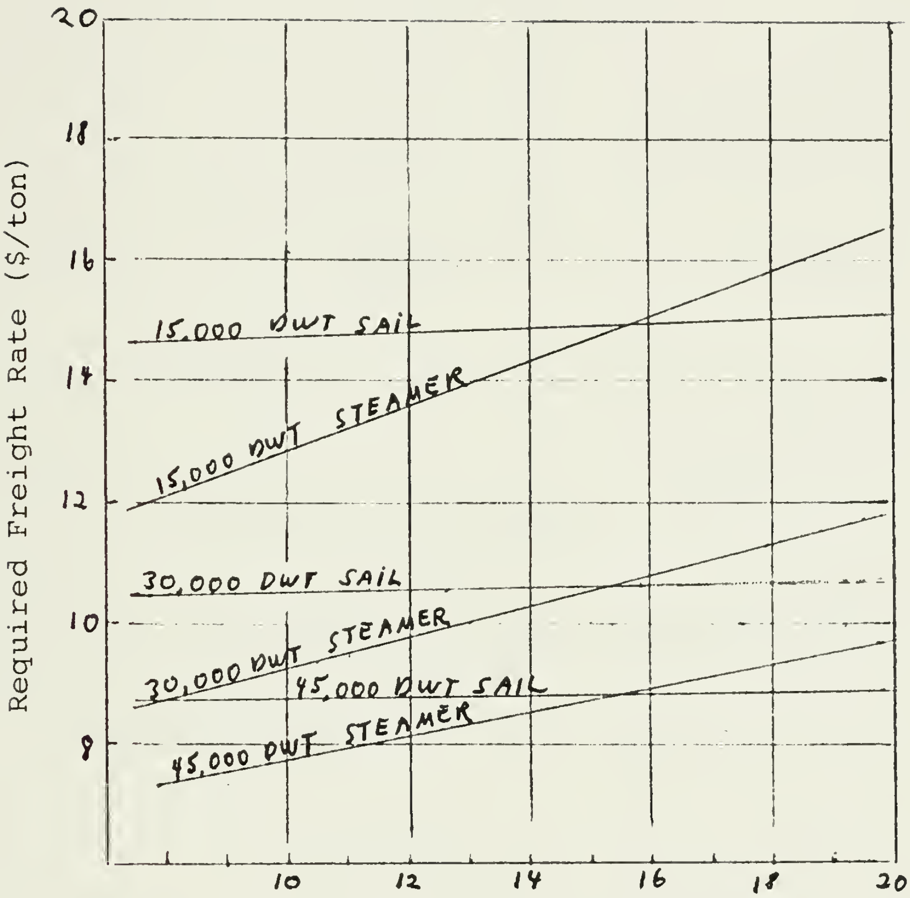

FIGURE 16. Sensitivity of Required Freight Rate to Fuel Price - New York to Liverpool

[a]The Michigan Study, which only extended fuel price to $20/BBL, clearly shows that at a December, 1979 fuel price of $24.44/BBL, all sized sailing ships require a lower freight rate than steam ships on all routes.

Source: Woodward, John B., et al. Feasibility of Sailing Ships for the American Merchant Marine. Ann Arbor: University of Michigan, 1975.

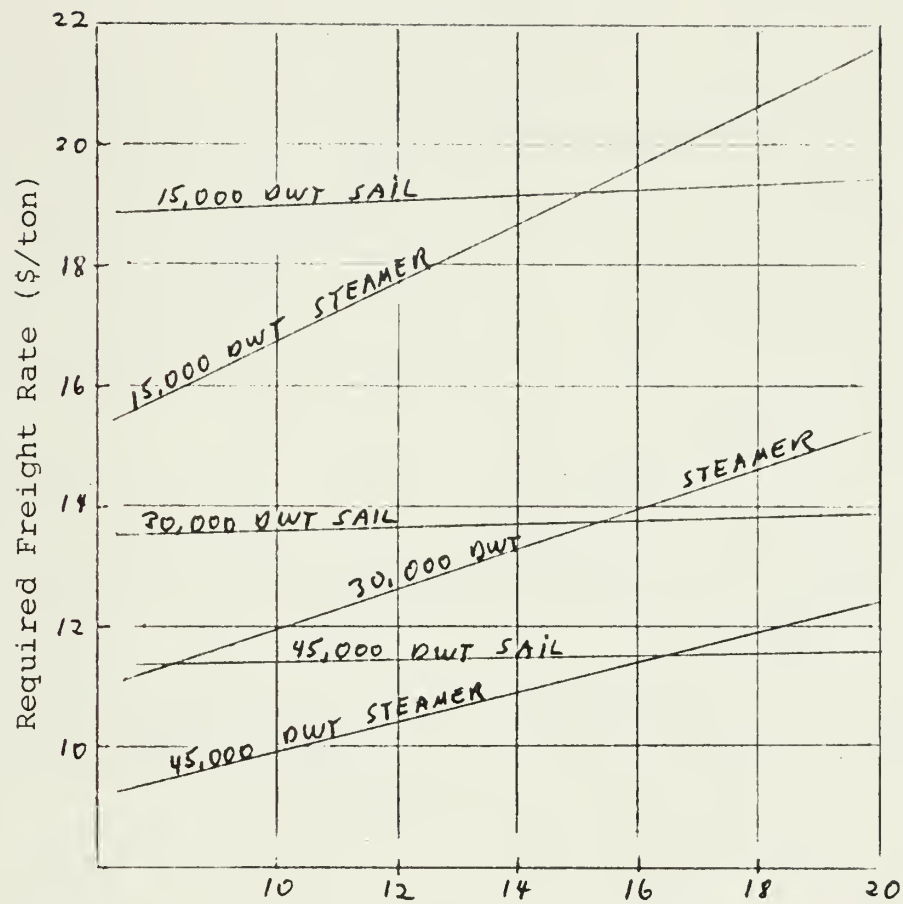

FIGURE 17. Sensitivity of Required Freight Rate to Fuel Price - Baltimore to Monrovia
Source: Woodward, John B., et al. <u>Feasibility of Sailing Ships for the American Merchant Marine</u>. Ann Arbor: University of Michigan, 1975.

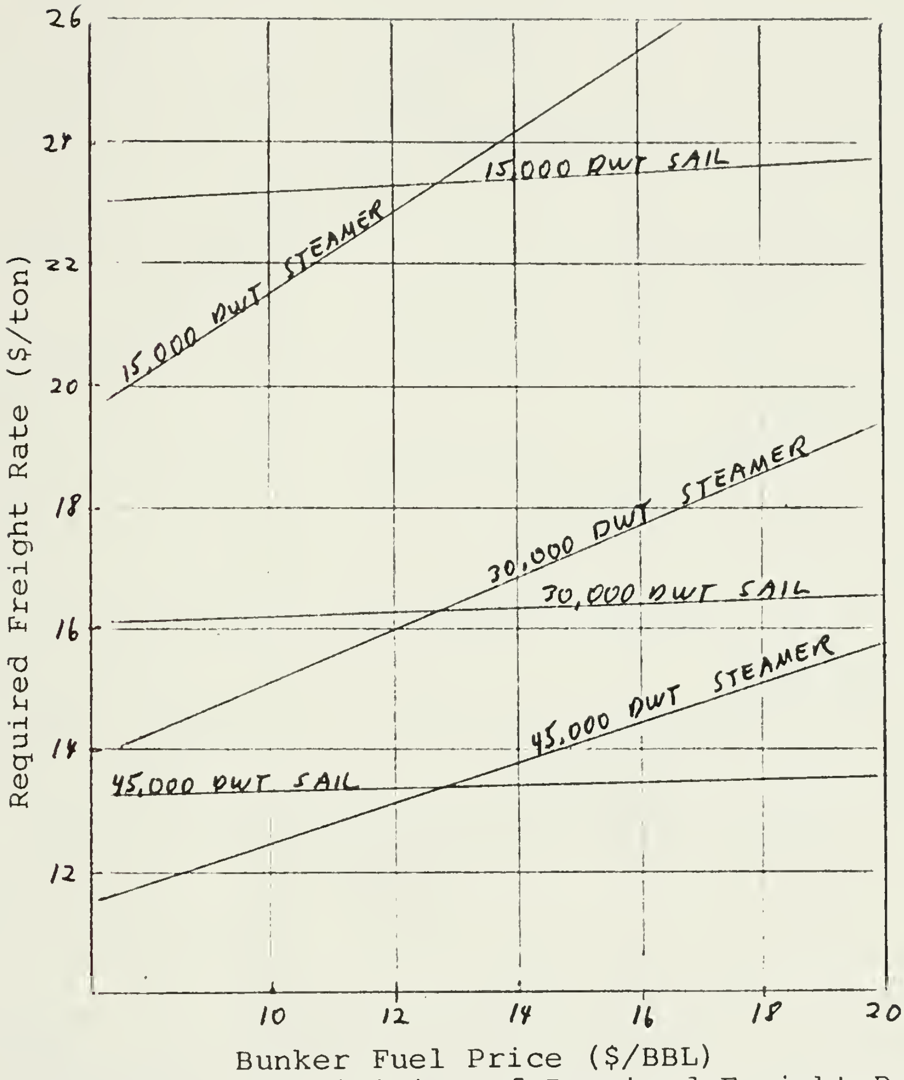

FIGURE 18. Sensitivity of Required Freight Rate to Fuel Price - Cape Flattery to Shanghai

Source: Woodward, John B., et al. <u>Feasibility of Sailing Ships for the American Merchant Marine</u>. Ann Arbor: University of Michigan, 1975.

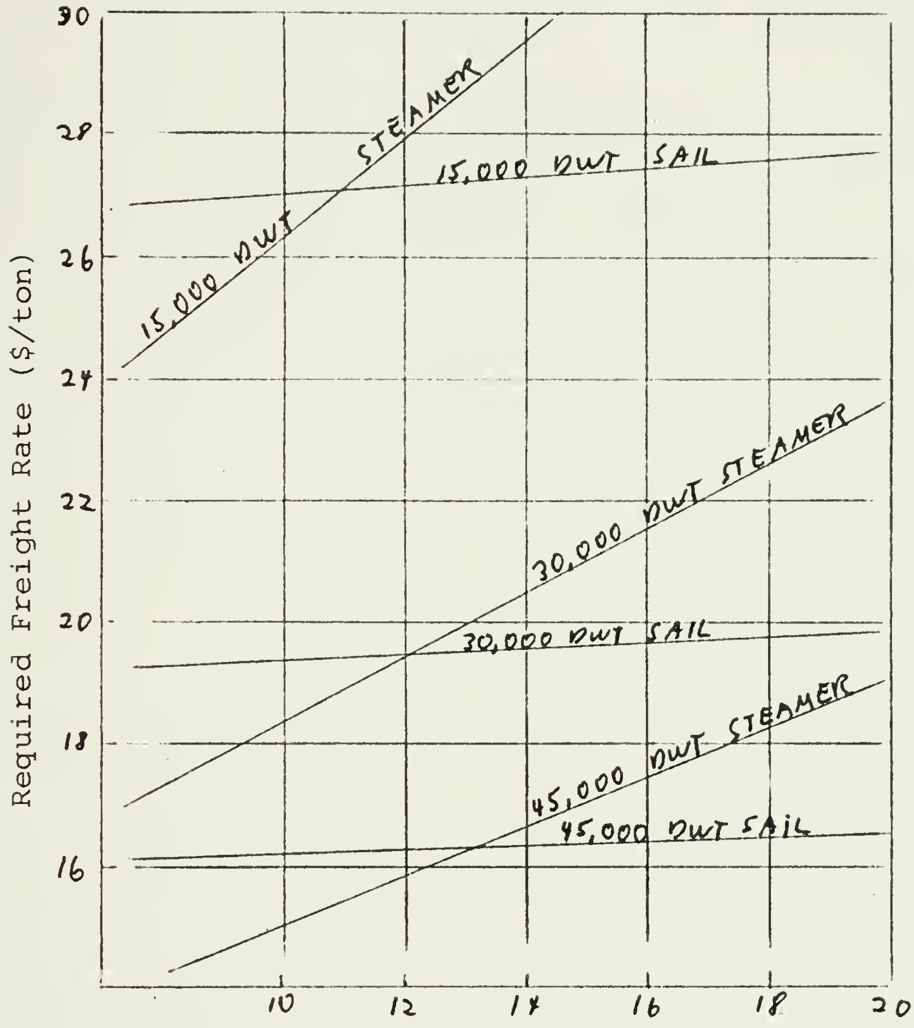

FIGURE 19. Sensitivity of Required Freight Rate to Fuel Price - San Francisco to Sydney
Source: Woodward, John B., et al. <u>Feasibility of Sailing Ships for the American Merchant Marine</u>. Ann Arbor: University of Michigan, 1975.

a prediction of fuel price increase based on a spiralling pattern well developed at the time of the study, should have resulted in a far less pessimistic tone of the published results.

Windrose Ships, Ltd., discussed earlier on pages 44 through 46 compared the economics of their proposed Sailiner with three motor-driven vessels. This economic assessment was reviewed by Lones.[12] In projecting operating costs, a price-escalated estimate of 1980 fuel costs of $115 per ton (metric ton assumed) was used. At this price, the sailing vessel showed lower daily operating costs and lower voyage costs per 100 cubic feet of cargo capacity. However, actual 1980 prices would support the sailing vessel proposal even more, as the December, 1979 price of ships fuel exceeded Windrose's estimate by $64.14 per ton.[13] An almost universal failure in fuel price prediction is reflected in Windrose's statement that "At the present time /1978/ bunker fuel is $84 per ton, but long term forecasts by the oil companies indicate that by 1985 it will be $170 and by 1990 $225 or more."[14] The actual price in December, 1979 of $179.14 per ton indicates that their 1985 prediction has been exceeded five years early.

Dynaship Corporation computed the percentage in RFR improvement shown by Dynaship over similarly sized diesel ships based on fuel prices in 1977 (date approximate).[15] Using ship sizes from 6,000 to 25,000 DWT on routes ranging from 2900 to 6600 miles round trip, Dynaships

averaging 10 knots showed RFR figures between 1.7 percent and 15.7 percent lower than those for diesel ships. Fuel costs have nearly doubled since these computer analyses were made. The RFR advantage of Dynaships would undoubtedly rise significantly using current costs.

Two additional studies have been published which address the economics of sail in general terms, rather than supporting a specific ship proposal. The first was published by Miles in 1975.[16] He compared two sailing vessels (5,000 DWT, 10 knots and 15,000 DWT, 15 knots) with four motorized vessels (15,000, 25,000, 60,000, and 100,000 DWT) over two routes under low growth and high growth economic scenarios. The low growth scenario assumed fuel price rises of eight percent per year, while the high growth scenario assumed a 12 percent increase. In no case was the smaller sailing vessel competitive. The larger sailing vessel, however, was competitive with the 15,000 and 25,000 DWT motorized vessels on both routes. When considered in the high growth scenario, the larger sailing vessel was competitive with the 60,000 DWT motorized vessel as well. This scenario was projected ahead ten years (1975 to 1985). It is interesting to note that ship's fuel prices in December, 1979 increased more than Miles' 12 percent per year estimate; in fact, the average yearly increase between 1975 and 1979 was 29 percent.[17] Miles' conclusions are optimistic and only cast doubt on

sailing ships in the event that speeds of 10 knots are achieved, rather than the projected 15 knots. At 11 knots the 15,000 DWT sailing vessel would be competitive only with the equivalent sized motorized vessel.

The second study concerning the general economics of sail was published by Couper in 1977.[18] He calculated that the RFR for sailing ships would be competitive with that for motorized vessels, and as fuel prices increase, the advantage of sail would correspondingly increase. He tempers this finding with a warning that slower passage times of sailing ships may result in higher manning costs and overshadow the savings in fuel costs. However, as discussed later in this thesis on pages 108 through 112 this speed differential may not be as great as expected.

Fuel prices continue to increase month by month, and sail becomes more economic. No end to this upward price spiral is foreseen. Many of the proposals cited above were optimistic when they were written, and are even more favorable today. An acute shortage, or even an ultimate absence of oil, is not an impossibility. Then sail power will become imperative.

Economy of Scale

An analysis of the shipping industry shows that merchant ships have changed in two important ways during the last 40 years. Ships have become more specialized and

the average size has increased. After World War II, the liberty ship and the T-2 tanker emerged as the backbone of ocean transport.

Today, the number of "break bulk" vessels, represented in part by the liberty ship type, are diminishing and being replaced with modular specializations such as containerships, roll-on, roll-off (RORO) vessels, and multi-cargo bulk carriers. The latter type, the bulk carrier,[19] will be discussed herein as the most applicable to modern sail propulsion. Most of the larger ship proposals discussed in Chapter II are intended as bulk carriers. Other configurations, such as container-ships and RORO are not ruled out, but bulk cargo handling operations appear the most conducive to modern sailing ships. The aspects of cargo handling are further discussed in Chapter IV.

An increase in ship size has taken place concurrently with the developments in specialization. This is illustrated most spectacularly in the size of tankers, which has risen from an average of 15,000 DWT for the T-2 to the current (1980) record holder, the Pierre Guillaumot, a French supertanker of 555,031 DWT.[20]

The most often cited reason for increase in ship size is economy of scale. A larger ship can transport more cargo, and can therefore proceed at a lower unit cost.

> In 1967 it cost three dollars and twenty cents per ton of oil in an 80,000 tonner to make the round trip from Rotterdam to Kuwait at the head

> of the Persian Gulf and back, going through the Suez Canal both ways. A 200,000 tonner could carry the same oil between the same points but via the Cape /of Good Hope/ for less than two dollars and forty cents a ton, making the longer route considerably cheaper than the traditional shorter one . . ."[21]

One large ship will cost less to build than two smaller ships of half the size of the larger. The larger will require only one crew, which may not be of greater number than that required for a smaller ship. One ship, instead of two or more smaller ships, will save on pilot fees, port charges, and general administrative costs. Additionally, one oil company claims that fewer large ships will result in fewer accidents.[22]

The pure economics of the above discussion are valid, at least when viewed in a very narrow spectrum. A shipper, shipowner, or consignee may very well profit from the economies of scale discussed. Additionally, the ultimate consumers of the product shipped may benefit from a lower price. However, additional factors must be considered, some of which are difficult to define in terms of dollars and cents. Size must also be considered in environic, as well as economic terms.

Perhaps the most obvious argument against large-sized ships, particularly supertankers, is the drastic environmental effect of a grounding or collision. Tankers become larger and accidents result in larger oil spills with increasingly devastating effects. In 1967, the 120,000 DWT

Torrey Canyon grounded on rocks off the Sicily Isles with ruinous environic effects on the adjacent coast. On March 16, 1978, the Amoco Cadiz grounded and spilled 220,000 tons of crude oil on the coast of Brittany, establishing a world record which holds to date. Unfortunately, this record will undoubtedly be exceeded in the future.

The oil companies may be right - fewer ships result in fewer accidents. The devastation of large oil spills, however, invalidates this argument for size. Cost of cleanup operations after the Amoco Cadiz incident have been estimated at $30 million.[23] Costs to the tourism and fishing industries are inestimable. The resultant death of marine and bird life, as well as the fouling of the earth, cannot be expressed in economic terms. Numerous smaller ships may, in fact, have more accidents simply by the laws of chance, but without the concentrated devastation associated with super-tanker accidents.

> Small-scale operations, no matter how numerous, are always less likely to be harmful to the natural environment than large scale ones, simply because their individual force is small in relation to the recuperative forces of nature.[24]

The insurance claims resulting from supertanker accidents are staggering. The Amoco Cadiz was insured for $30 million, $12.4 million of which was covered by Lloyds of London.[25] An increase in frequency of accidents could be ruinous for the insurers. "As long as the disaster

remains an isolated incident, maritime insurers should be able to handle the loss. But as one Lloyds' spokesman warns, 'If we have two or three of these a year, it would be a different kettle of fish.'"[26]

Insurance rates will undoubtedly rise as these disasters become more common. There is no precedent for shipping insurance and disaster of this magnitude, as they go beyond the present commercial understanding of insurance. This is a considered, but unresolved environic argument. Coastal economies are in jeopardy, as marine communities, both human and natural, are exposed to a new danger which is virtually perpetual as long as the oil economy exists.

The above argument against ship size is essentially one against catastrophic damage to the environment. The following discussion deals with physical aspects of ship size. A consideration to be made is the inability of many large ships to call at ports which have evolved in service to relatively small vessels. Restrictions such as depth of channel, dimensions of turning basins, length of piers, and capacity of cargo handling equipment may prohibit large ships. This, coupled with the development of modern "superports" to support the new specialized ships, has resulted in the economic decline of many small ports. Shippers find it cheaper to ship larger quantities of goods to centralized ports, then to distribute them via land transport such as truck or rail. The impact of modern commercial sailing

ships on this phenomenon will be discussed in detail in Chapter IV.

Since bulk carriers are of primary interest here, a detailed look at their size evolution is in order. This is illustrated in Table I, which compares the frequency of bulk carriers in various size classes in 1967 and 1977.

These size data illustrate two significant facts. First, it is obvious that bulk carrier average size is increasing. Secondly, an important parallel exists between the most popular size classes of modern bulk carriers and the ship size deemed as technologically feasible for wind power.

In the first instance, inspection of Table I shows that while all size classes experienced an increase in number of ships from 1967 to 1977, sizes of 24,000 DWT and below dropped in their percentage of total ships. With few exceptions, all size classes above 25,000 DWT increased in percentage. Some size classes experienced dramatic growth rates: 40-45, 60-64, 65-69, 75-79, 85-89, 95-99, and 100 thousand DWT and over. As of December 31, 1977 there were 113 dry bulk carriers and 210 combination liquid and dry bulk carriers between 100,000 and 199,999 DWT. Thirty-three of the latter type were 200,000 DWT and larger.[27] Clearly, bulk carriers are becoming larger.

Despite the increase in ship size, it is important to note that 77.4 percent of bulk carriers in 1977 were smaller than 45,000 DWT. This point is of special significance, as

TABLE 1

FREQUENCY OF BULK CARRIERS BY SIZE CLASS

DWT (000's)	Number of Ships 1967	1977	Percent of Total 1967	1977	Percent Increase 1967 to 1977
under 10	710	723	30.0%	14.7%	1.8%
10-14	224	246	9.5	5.0	9.8
15-19	436	760	18.4	15.4	74.3
20-24	321	554	13.6	11.2	72.6
25-29	163	759	6.9	15.4	365.6
30-34	108	344	4.6	7.0	218.5
35-39	115	285	4.8	5.8	147.8
40-44	40	143	1.7	2.9	257.5
45-49	50	96	2.1	1.9	90.0
50-54	65	171	2.7	3.5	163.1
55-59	39	110	1.6	2.2	182.1
60-64	15	93	0.6	1.9	520.0
65-69	19	73	0.8	1.5	284.2
70-74	29	79	1.2	1.6	172.4
75-79	11	63	0.5	1.3	472.7
80-84	11	29	0.5	0.6	163.6
85-89	3	19	0.1	0.4	533.3
90-94	4	11	0.2	0.2	175.0
95-99	3	19	0.1	0.4	533.3
100 and over	2	356	0.1	7.2	17,700.0
Total	2,368	4,932			

SOURCE: Bulk Carriers in the World Fleet as of December 31, 1977, U.S. Department of Commerce, Maritime Administration, January, 1979, p. x.

this is the size deemed as the upper limit of technological feasibility of modern wind powered cargo ships. A return to wind power does not mean a return to ships of extremely small size, which would be viewed as "uneconomic." Over three-quarters of the ships in the world's bulk carrier fleet are of a size class applicable to sail power.

An interesting attempt to disprove the economic palatability of sailing ships was presented by Close.[28] He compared sailing ships of 15,000 and 50,000 DWT to a motorized vessel of 100,000 DWT, and concluded that the latter was more economic. This is not surprising, and surely the same results would be obtained had he compared the larger motorized vessel with smaller motorized ships. The article merely clouds the issue of economy of scale. The fact remains that relatively small bulk carriers (under 50,000 DWT) are very popular with the shipping industry, and sail power has been convincingly proposed as a viable means of propulsion.

Ship Speed

Speed of delivery is an essential parameter in shipping certain high value or perishable goods. Consistency of delivery is important in others, such as where a stockpile of a commodity must be maintained within certain limits.

Trades which require high speed of delivery, particularly perishable foodstuffs, are becoming increasingly dependent upon specialized shipping, including containerships which carry refrigerated units. The average speed capability of containerships in the world fleet is 19 knots, with some having a 30 knot speed.[29]

Bulk carriers, which have a lower speed requirement, average 14 knots.[30] In making speed comparisons of modern wind-powered ships with motorized ships, the average speed of the bulker should be used. This is the trade which appears most suitable for the former type.

Table 2 shows the speed predictions for several of the modern wind-powered ship proposals cited in Chapter II. The average speed is approximately 11 knots.

Table 3 shows the number of ships in each speed category for bulk carriers. Three hundred and forty-nine ships, or 7.1 percent of the total, are in the speed categories of 11 knots and less. Although this illustrates that wind-powered ships will be slower than the majority of motorized ships, they will be immediately competitive with 7.1 percent of total bulk traffic at the outset of sail trading. This figure is very impressive at the initiation of this mode of transport when compared with other new forms of transportation at the moment of their introduction. When first introduced, steamships were not economically competitive with any sailing ships, and remained uncompetitive

TABLE 2

PREDICTED SPEEDS OF PROPOSED MODERN WIND-POWERED CARGO SHIPS

Proposal	Predicted Average Speed
Dynaship	10 Kts
Windrose Sailiner	12 kts
Bergesen Proposal	11 kts
Michigan Study Designs	9.2-10.99 kts
Western Flyer Project	9.8 kts
Warner/Hood Design	12.5 kts
Carson Bulk Carrier	12 kts
Average	11.06 kts

Source: Literature Cited in Chapter II Describing Individual Ship Proposals.

TABLE 3

SPEED OF WORLD BULK CARRIERS
AS OF DECEMBER 31, 1977

Speed (Knots)	Number of Ships
9 and under	36 [a]
10	103 [a]
11	210 [a]
12	272
13	280
14	1124
15	2036
16	7111
17	141
18 and over	19
Total	4936

[a]The number of ships with speeds of 11 knots or less represent 7.1 percent of the total.

Source: U.S. Department of Commerce Maritime Administration, A Statistical Analysis of the World's Merchant Fleets as of December 31, 1977, p. 157.

for several years. An analysis of the initiation of jet passenger service would undoubtedly prove a similar relationship with conventionally powered aircraft. Modern sail power is unique in this ability to be immediately competitive upon its inception.

This 7.1 percent figure, when associated with ports, has additional significance in that many smaller ports are less accessible, or in some cases exclusive, to larger vessels. Therefore, sail can combine its competitive edge with the prospects of filling a need for trade in smaller ports, resulting in an economic revival of the latter. This impact on ports is discussed in detail in Chapter IV.

These environic relationships concerning speed and place can be joined with that of quantity, which was discussed earlier under the topic of economy of scale. In the context of size, or carrying capacity, modern sailing ships will be competitive with over three-quarters of existing bulk carriers. In speed, they will be able to compete with over seven percent. This constitutes a fundamental SPEED-PLACE-SIZE environic relationship.

Construction Cost

Construction costs of modern wind powered cargo ships are predicted to be approximately the same as those for motorized ships. Costs for the masts and sails, or other wind propulsion devices, will likely be compensated for by the savings in main propulsion system costs.

Warner and Kossa report that early (probably mid-1950's) estimates by shipbuilders Blohm and Voss of Germany put sailing vessel construction costs at 10 percent less than motorized ships.[31] The Michigan Study estimates construction costs of sailing vessels to be 10 percent higher than a comparable dead weight motorized vessel.[32]

Confirmation of construction costs, particularly for masts, sails, and the associated machinery, must await the actual building of the first vessel. This will be a pioneering project, as sails and masts of this type have never been constructed.

Actual construction cost estimates in today's economy are risky, but a bulk carrier of 30,000 DWT cost $13.5 million in 1975.[33] Increasing costs of energy, material, and labor will steadily increase this cost. However, the sail/motorized differential should remain equal.

Cargoes

Very little has been written about specific cargoes for wind powered cargo ships. Most proposals for these

ships intend their employment in the bulk cargo trades. Bulk cargo is defined as "a homogeneous mass of unpackaged goods, such as coal, ore, grain, oil, or sand."[34]

Couper has allocated certain bulk cargoes to sailing ships on the basis of sensitivity to time and applicability to economies of scale.[35] Cargoes which are perishable, or otherwise sensitive to time, or have high demand characteristics and are conducive to economies of scale (oil and coal) are not allocated to sail. Others, which are free of these characteristics, particularly if the trade patterns are on wind-reliable routes, are applicable to sail transport. He specifically cites grain, wool, jute, sugar, and cotton.

Modern wind-powered vessels also show promise as general cargo, or break-bulk carriers. An important consideration is cargo handling, necessitating deck or shore mounted cranes that would not suffer interference from the masts. General cargoes could include a wide variety of packaged goods (canned foodstuffs, chemicals, fertilizer, small machinery), lumber and other building materials, or baled commodities.

Investment Opportunities

Bulk carriers represent 20 percent of the world merchant fleet, but only two percent of the U.S. merchant fleet. American bulk shipping has been described as "an

absolute disaster"[36] and in "dismal condition."[37] As of December 31, 1977, the U.S. fleet included only 16 dry-bulk carriers and two combination ore/bulk carriers.[38] Combined, these vessels represent 529,300 DWT.

The above statistics are indeed remarkable, considering that the combined U.S. annual import and export of dry bulk commodities is approximately 300 million tons.[39] In 1978, U.S. ships carried only 1.9 percent of this trade.[40] The U.S. is dependent upon the shipping of other nations to transport these commodities. Since several strategic materials are involved, this situation is clearly not in the best interests of the U.S.

The 1936 Merchant Marine Act, which allowed operating and construction subsidies for ships, did not include bulkers. This was not intentional; bulk carriers simply did not exist then. Modern bulk carrier construction has thus been inhibited since the type's inception in the 1940's explaining the statistics cited above.

This trend may be reversed, as President Carter, on July 20, 1979 indicated his recognition of the problem and his willingness to remedy the situation.[41] He called for legislation that would accelerate the revitalization of the U.S. bulk fleet to the level commensurate with the leading position of the U.S. in the bulk trades.

A proposed rebuilding of the U.S. bulk fleet presents a timely opportunity for the building of wind-powered

ships. The proposed legislation will create the investment opportunities. The economic and environic rationality of wind power has been shown. It is imperative that far-sighted investors build these ships to ensure a substantial portion of the U.S. merchant fleet becomes virtually independent of high-priced and dwindling fossil fuels.

LEGAL CONSIDERATIONS

Maritime law is a complex body of knowledge which has evolved through custom, legislation, and precedent. It originated in the days of sail. The advent of steam, with larger and more complex ships, brought significant changes. Maritime law may face another evolutionary transformation with the reintroduction of wind power at sea. Yet, a sailing ship is still a ship, regardless of the differences in propulsion. The basic legal structure will apply, although a large scale appearance of wind-powered vessels may necessitate certain modifications. Anticipation of these requirements will facilitate an ordered reintroduction of wind power. Even the most diligent foresight, however, will leave gaps. Some problems will simply have to be discovered.

Licensing and Classification

Vessels of all types are subject to many regulations of organizations and international treaties concerning ship construction, safety, manning and labor practices. Lawrence complains of bureaucratic delay when dealing with the U.S. Maritime Administration concerning government guarantees on ship mortgages.[42] He finally received an admission that sailing ships will be considered for these guarantees under the Merchant Marine Act. Lawrence describes similar frustration on the part of Dynaship Corporation in application to the U.S. Coast Guard for loadline and stability approval of their design. Dynaship Corporation has been successful, however, in obtaining American Bureau of Shipping classification approval of the vessel so that insurance can be obtained for the ship and its cargoes.[43]

Construction of modern wind-powered cargo ships is inevitable. Now is the time to promote legislation and overcome bureaucratic inertia to allow a smooth integration of these ships into the maritime economy. A sense of urgency is required at both the legislative and administrative levels of government.

Registry

Every merchant vessel, regardless of its ownership, must be registered in a specific country. Some countries,

because of the nature of their laws concerning ship safety, crew constituency, labor relations, and taxes, have become popular for ship's registry. They are known as "flags of convenience." Liberia and Panama are notable in this regard. Although the ships' owners are citizens of another country, there is some doubt as to control of these ships in wartime. Approximately 49 percent of U.S.-owned ships were registered under the Liberian flag in 1968.[44]

The proposed legislation cited earlier under Investment Opportunities should diminish the tendency toward foreign registry of U.S. ships. The domestic registry of a fleet of modern sailing ships would represent a significant strengthening of the U.S. flag merchant fleet. American sailing ships can once again carry a significant share of U.S. imports and exports.

Navigation Rules

The International Regulations for Preventing Collisions at Sea, 1972, were developed under the auspices of the United Nations Maritime Consultive Organization (IMCO).[45] These regulations must be followed by all vessels navigating upon the high seas. Additionally, all vessels navigating upon certain inland waters of the United States are subject to the U.S. Inland Rules.

Specific provisions are made in the above rules and regulations for sailing ships. Rule 3(c) of the

International Regulations defines the term "sailing vessel" as "any vessel under sail provided that propelling machinery, if fitted, is not being used."[46] The Inland Rules state that "every steam vessel which is under sail and not under steam is to be considered a sailing vessel, and every vessel under steam, whether under sail or not, is to be considered a steam vessel."[47] Therefore, the sighting of a vessel with sails and obviously under sail power is insufficient evidence to classify her as a sailing vessel, in the context of these rules. Furthermore, determination of the fact that the vessel is under motorized power can be extremely difficult. The rules fortunately allow for a clarification of this dilemma. International Rule 25(c), allows sailing vessels over 12 meters in length to show a special light configuration at night. A sailing vessel may ". . . exhibit at or near the top of the mast, where can best be seen, two all-around lights in a vertical line, the upper being red and the lower green . . ."[48] During daylight, Rule 25(e) requires vessels underway under sail and also being propelled by machinery, to exhibit forward, where it can be best seen, a conical shape, apex downwards.[49] The lights prescribed in Rule 25(c) are optional, and the rule does not clearly state that the lights will be shown when the vessel is under sail power only. A change to make the light mandatory when the vessel is under sail power alone, and to prohibit its use otherwise is needed.

The Inland Rules do not call for the masthead light configuration prescribed by the International Rules. Article 14 of the Inland Rules states that "A steam vessel proceeding under sail only, but having her funnel up, may carry in daytime, forward, where it can best be seen, one black ball or shape two feet in diameter."[50] This rule is outdated and confusing. Both Inland and International rules should be brought into alignment.

International Rule 9(b) states that "A vessel of less than 20 meters in length or a sailing vessel shall not impede the passage of a vessel which can safely navigate only within a narrow channel or fairway."[51] Initially, this rule appears to show prejudice against sailing vessels. It is most likely, however, that sailing vessels will be under auxiliary engine power in this situation and the rule would not apply. Mandatory use of auxiliary power in this situation may be a necessary change to the rules.

International Rule 10(j) is similar to Rule 9 in that it states in part that "a sailing vessel shall not impede the safe passage of a power-driven vessel following a traffic lane."[52] These traffic lanes are part of IMCO Traffic Separation Schemes to prevent collisions. Mankabady argues that use of auxiliary power should be mandatory for sailing vessels using these separation schemes.[53] However, many of these schemes are in unrestricted waters where sail power may be entirely sufficient for safe

navigation. The use of auxiliary power should be a matter left to the prudence of the master.

In situations on the high seas where none of the special circumstances discussed above exist, sailing vessels have the right-of-way over motorized vessels. Rule 18(a) states that "A power-driven vessel underway shall keep out of the way of a sailing vessel."[54] This is an historical custom which should remain in the rules. A course change by a sailing vessel involves trimming the sails or other wind propulsion devices, as well as a shift of the rudder. A motorized vessel contends only with the latter.

Both the International and Inland Rules address the situation of right-of-way when two sailing vessels meet. In the future, sailing vessels may not all be powered by sails, in the traditional sense. Special rules may be required, for instance, when a Dynaship and a wind-sail ship, or a windmill-powered ship converge. Maneuvering characteristics of each type will require consideration. These are additional examples of problems to be discovered and solved with experience.

Experience under sail is almost non-existent in masters and officers of today's motorized vessels. As more sailing vessels appear on the seas, an understanding of wind power and its limitations will be required on the part of all mariners. Collision-avoidance action may be required earlier than in a situation with two motorized

vessels. On the other hand, a sailing ship master must exercise prudence and use his auxiliary engines to avoid embarrassing or dangerous situations.

A mutual disdain was evident on the part of sailing and steamship masters in the late eighteenth and early nineteenth centuries. Mutual respect in the highest tradition of professional seamanship, will be paramount for the safe and orderly coexistence of sail and conventionally powered ships.

Shipboard Safety

The preservation of human life and limb is of paramount importance on any ship at sea and has long been accepted as so. This emphasis on safety is sustained by several interested organizations including, in the U.S., the Coast Guard, the Maritime Administration, the Occupational Safety and Health Advisory Board (OSHA), and the seamen's unions. Many shipowners feel burdened by costly and seemingly unnecessary regulations.[55] An important legislative need is that for the establishment of a Seaman's Compensation Act, similar to Workman's Compensation for land-based employees. "Mainly because his employees can and do sue him and often collect enormous sums, the cost of Protection and Indemnity insurance for the American /ship/ owner is considerably higher than /for/ his foreign competition."[56] Although this problem is common to all

vessels, its resolution will help pave the way for the introduction of the wind-powered ship.

Modern sailing ships will certainly be safer than their forerunners of the late eighteenth and early nineteenth centuries. The requirement to go aloft on a regular basis has been eliminated in all proposals except one, the Windrose Sailiner. In all others, sailhandling will be done automatically from enclosed deck stations. Emergency work aloft, when and if required, can be accomplished by a minimum number of specially trained personnel.

Other ship safety considerations will be similar to those of conventional motorized ships. Overall ship safety and stability will be ensured during vessel design.

There is a possibility that labor unions may balk at the introduction of wind power in ships. Preliminary negotiation is necessary to prevent embarrassment or financial disaster during initial operation of these vessels. This is illustrated by the example of an early American containership. The Gateway City arrived in Puerto Rico in 1957 to find that the local labor refused to unload the ship.[57] The ship had to sail without unloading.

There are some preliminary indications that sailing ships will be accepted by seamen's unions. Windrose, Ltd. has received letters of support from the Merchant Navy Officers Association, the U.K. Department of Trade, the National Union of Seamen, and the Sealife organization.[58]

In the U.S., the AFL/CIO Maritime Trades Department commented on proposals for modern sailing ships in their Maritime Newsletter.[59] No specific comments were made concerning their acceptance of the idea, but the general tone of the article was positive.

Marine Insurance

One might speculate that ships with wind propulsion devices may be viewed as a greater risk than motorized ships by marine insurers. The opinion of Lloyd's of London, an organization which may be considered the "voice" of marine insurance, indicates a different attitude. Their philosophy shows a great deal of faith in this mode of propulsion. Mr. M.D. Fletcher, secretary of Lloyd's Underwriters' Association sees no "unique aspects in insuring modern sailing cargo ships" and states that "such risks do not present marine underwriters with any particular difficulty and the clauses that are generally used serve equally for sailing and powered vessels."[60]

FOOTNOTES

[1]E.F. Schumacher, Small Is Beautiful (New York, 1973), p. 41-42.

[2]Dynaship Offices, Palo Alto, California, August 2, 1978.

[3]Lloyd Bergeson, "Sail Power for the World's Cargo Ships," Technology Review, March/April, 1979, p. 23.

[4]Time Magazine, December 19, 1979.

[5]U.S. Department of Energy, Monthly Energy Review, November, 1979, (Washington, D.C., 1979), p. 77. These prices represent average actual domestic prices of crude oil at the wellhead. $8.57 is the 1977 average and $13.22 is the July, 1979 price based on preliminary data.

[6]Residual fuel oils are those that remain after the distillate fuel oils and lighter hydrocarbons have been boiled off in refining operations. Bunker C, the common fuel oil used by steam-driven ships, conforms to the specifications for No. 6 residual fuel oil. Therefore, these prices are representative of those paid to bunker, or fuel, ships.

[7]U.S. Department of Energy, Monthly Energy Review, March, 1980, (Washington, D.C., 1980), p. 88. The December, 1979 price was the latest available at the time of writing.

[8]Eugene Heil, "Slow Speed Marine Diesel Engines," Marine Engineering/Log, October, 1979, p. 47.

[9]John B. Woodward, et al., "Feasibility of Sailing Ships for the American Merchant Marine," Department of Naval Architecture and Marine Engineering, University of Michigan, for the Maritime Administration of the U.S. Department of Commerce, No. 108, February, 1975, p. 53. Hereafter referred to as Woodward, "Michigan Study."

[10]Hugh G. Lawrence, "Sailing Cargo Ships," Oceans, March-April, 1978, p. 59.

[11]December, 1979 Average Retail Price, No. 6 Residual Fuel Oil.

[12]Trevor Lones, "Getting the Wind Up Over Future Oil Supplies," Seatrade, December, 1978, p. 77-81.

[13]December, 1979 price of $24.44 per barrel multiplied by 7.33 barrels per metric ton equals $179.14/ton, or $64.14 greater than Windrose's estimate of $115/ton.

[14] Windrose Ships Ltd., International Sailiner Brochure, undated.

[15] Dynaship Corporation, "Typical Required Freight Rate Comparisons Between Dynaship and Motor Ships," undated.

[16] A.S. Miles, "The Economics of Commercial Sail," The Royal Institution of Naval Architects, Occasional Publication NR 2, The Future of Commercial Sail, 1976, pp. 81-88.

[17] Based on data from U.S. Department of Energy, "Monthly Energy Review," October, 1977 and January, 1980. The 1979 average price increase was calculated through the December, 1979 price.

[18] A.D. Couper, "The Economics of Sail," The Journal of Navigation, May, 1978, pp. 164-171.

[19] A single-decked vessel designed to carry bulk commodities.

[20] World Almanac for 1980, p. 115.

[21] Noel Mostert, Supership, (New York, 1974), p. 73.

[22] Exxon Corporation, Very Large Crude Carriers (VLCC's), Exxon Background Series 11/75, (1975), p. 6.

[23] James C. Bridgman, "Who Pays," Oceans, July-August, 1978, p. 59.

[24] E.F. Schumacher, Small is Beautiful, (New York, 1973), p. 36.

[25] Business Week, April 17, 1978, p. 48.

[26] Business Week, April 17, 1978, p. 48.

[27] U.S. Department of Commerce, Maritime Administration, A Statistical Analysis of The World's Merchant Fleets as of December 31, 1977, pp. 195 and 233. Hereafter cited as MarAd, "World's Merchant Fleets."

[28] H.M. Close, "Commercial Sailing Vessels - An Economic Assessment," The Naval Architect, September, 1978, pp. 166-168.

[29] MarAd, "World's Merchant Fleets," p. 80.

[30] MarAd, "World's Merchant Fleets," p. 157.

[31]William L. Warner and Miklos M. Kossa, "Updating An Ancient Art - Research and Development Toward Modern Wind-Powered Cargo Ships," paper presented at Society of Naval Architects and Marine Engineers Symposium, San Francisco, May 25-27, 1977, p. 16.

[32]Woodward, Michigan Study, p. 53.

[33]United Nations Conference on Trade and Development, Review of Maritime Transport, 1975, (New York, 1977), p. 26.

[34]W.A. McEwen and A.H. Lewis, Encyclopedia of Nautical Knowledge, (Cambridge, Maryland, 1953), p. 72.

[35]A.D. Couper, "The Economics of Sail," The Journal of Navigation, May, 1977, p. 167.

[36]James R. Barker, "The Cargo Crisis for American Bulk Shipping," American Merchant Marine Conference 1978 Proceedings, October, 1978, p. 29.

[37]M. Lee Rice, "U.S. Dry Bulk Carriers - A National Need," American Merchant Marine Conference 1978 Proceedings, October, 1978, p. 36.

[38]MarAd, "World's Merchant Fleets," pp. 197 and 235.

[39]M. Lee Rice, "U.S. Dry Bulk Carriers - A National Need," American Merchant Marine Conference 1978 Proceedings, October, 1978, p. 36.

[40]L. Edgar Prina, "'Cargo Moves Ships': Action At Last on the Maritime Front," Seapower, September, 1978, p. 28.

[41]M. Lee Rice, "U.S. Dry Bulk Carriers - A National Need," American Merchant Marine Conference 1978 Proceedings, October, 1978, p. 28.

[42]Hugh G. Lawrence, "Sailing Cargo Ships," Oceans, March-April, 1978, p. 60.

[43]Personal conversation with Mr. William L. Warner, Dynaship offices, Palo Alto, California, August 2, 1978.

[44]Earl W. Clark, Hoyt S. Haddock, Stanley J. Volens, The U.S. Merchant Marine Today, (Washington, D.C., 1970), p. 12.

[45]U.S. Coast Guard "Navigation Rules," CG-169, May 1, 1977. Hereafter cited as CG-169.

[46]CG-169, p. 4.

[47]CG-169, p. 109.

[48]CG-169, p. 32.

[49]CG-169, p. 32.

[50]CG-169, p. 115.

[51]CG-169, p. 12.

[52]CG-169, p. 14.

[53]S. Mankabady, "A Legal Look at Sailing Ships," symposium on technical and economic feasibility of commercial sailing ships, Liverpool Polytechnic, February 26, 1976.

[54]CG-169, p. 20.

[55]Philip Steinberg, "Impact of Government Regulations on the Maritime Industry," American Merchant Marine Conference 1978 proceedings, October, 1978, pp. 61-62.

[56]John H. Cassedy, "Liabilities and Insurance for the American Flag Ship," American Merchant Marine Conference 1978 proceedings, October, 1978 p. 64.

[57]R.O.C. Swayne, "The Container 'Revolution'," Ship's Cargo - Cargo Ships, (Hounslow, England, 1979), p. 114.

[58]Trevor Lones, "Getting the Wind Up Over Energy Supplies," Seatrade, December, 1978, p. 79.

[59]AFL/CIO Maritime Trades Department, monthly newsletter, July, 1979.

[60]M.D. Fletcher, Secretary, Lloyd's Underwriters' Association to Bruce G. Koltz, December 29, 1978, author's personal files.

CHAPTER IV

ENVIRONIC DESIGN AND PLANNING FACTORS

Introduction of wind power for commercial shipping, which disappeared more than fifty years ago, will have far-reaching consequences for the entire marine transport industry. Ship-owners, ship's personnel, import and export firms, port authorities, traffic coordinators, ship's suppliers, ship-builders, and the populations of seaports will be touched by a large-scale reintroduction of sail. Creative and far-sighted planners, appreciating the environic consequences of this event, can anticipate these challenging effects and ease the transition. The most significant impact of sail is the potential for the revival of small port economy.

REVITALIZATION OF SMALL PORT ECONOMY

The environic consequences of the historic rise of sail, the replacement of sail by steam, and the potential revitalization of sail power are considered here as primary design and planning factors for seaports and shipyards. The term port comes from the Latin "Porta," meaning passage or gate. Sea-ports and airports are the fundamental types, and seaports can be further described as "steamports" and "sailports." This designation refers to the particular port's compatibility with and subsequent use by steam- or sail-powered ships. Some ports, due to geographic and prevailing wind conditions

could have been, or could potentially be designated sail-ports.

The following is a brief discussion on port development with an emphasis on location with regard to prevailing wind patterns. Then, after an identification of the above influence, the effects of the replacement of sail by steam are discussed in an attempt to establish that certain ports lost favor with the passing of sail. In other words, ports that were favorable to sailing ships no longer held an advantage, and other ports became dominant for a variety of physical or economic reasons. Then the hypothesis is put forth that seaports which languished with the rise of steam may have potential as revitalized sailports with the reintroduction of sailing cargo ships. The effects of this reintroduction on shipbuilding and repair in the context of coastal economy are also considered.

The Rise of Seaports in the Era of Sail

Seaports have been characterized as "the first population centers, the gateways to the hinterland, the essential building blocks of first local, then state and regional development."[1] America's first colonies were founded along the Atlantic coast. Even more significant than the event of the colonists' first land contact at the coast, was the advantage of remaining there and retaining waterborne

communications with the homeland. Thus, the colonists settled and the first seaports developed. Growth of these original colonies and the establishment of others favored the coastline, as land transportation was difficult, time consuming, and costly. "Consequently, the colonies and later the Atlantic seaboard states relied on water transportation not only for contact overseas but also for exchanges with each other."[2]

Innumerable characteristics concerning the quality of place influence port location. Included are parameters which are pertinent to shipping, such as size of harbor, degree of protection afforded, depth, and tide and current information. Other physical, social, and economic factors such as climate, geography, agricultural productivity, and availability of natural resources also influenced original site selection. It is unlikely that any single factor, such as navigability by sailing ships, dictated site selection. Conversely, the inability of a sail-powered vessel to navigate within an area ruled out the potential colonization of that site. For example, perhaps the combination of prevailing winds and particularly strong tidal currents presented ships with unusual risks. This consideration of navigation and seamanship under sail was undoubtedly an important factor in early seaport site selection. Extensive study of individual sites may reveal this to be the controlling factor in some instances, but time and space restraints

rule out further study herein. An illustrative example is presented, however, in the development of Boston, Massachusetts as a major port and its decline due to the competition of New York. Similar relationships involving other U.S. or world ports provide potential for further studies.

The port of Boston, founded in 1630 is blessed with an admirable harbor, and deep natural channels and roadsteads. Island breakwaters create nearly 4,000 acres of sheltered anchorages only a few miles from the sea. Bold headlands aid the pilotage of vessels through the channels.[3]

Port Series No. 3 for Boston describes the ports' wind characteristics: "Prevailing winds are from the southwest for the months of May to November, and from the northwest and west, December through April. Winds of 32 miles per hour or higher may be expected at least one day in every month; gales are more frequent and severe in winter."[4] These prevailing westerly winds are dependable and undoubtedly helped Boston become an important port in the days of sail. A ship leaving Boston for Europe had clear sailing with a good chance of following winds. The eastbound trip generally took about three weeks. Westward passages, however, averaged five weeks and often took up to eight weeks in the winter. The wind patterns and their associated ocean currents made the southern route easier to sail westward. A vessel would proceed southwest from England to approximately 20° North latitude, then head west in the trade winds toward the West

Indies and north toward New England. An alternative route took a vessel around the north of Ireland then west toward the southern tip of Greenland before heading southwest down the coasts of Newfoundland and Nova Scotia. This route had its obvious disadvantages in winter.

Boston was "above all a shipping town."[6] Although backed by an important industrial base, the port lacked both a hinterland rich in agriculture products or minerals and a natural waterway to the interior.[7] Taking advantage of this situation, ". . . Bostonians seemed early to understand that wealth was made not through the production of commodities, nor even through its simple carriage, but rather through its clever distribution."[8] Thus, Boston became an entrepot for New England. The port, "owning the most shipping, serving as the principle emporium for the distribution of highly-priced European goods . . . clearly led the field. Indeed, a considerable portion of the goods from England which reached New York each year came <u>via</u> Boston."[9] In 1807, Massachusetts' registered tonnage of ships engaged in foreign commerce was over twice that of her nearest rival, New York.[10]

This brief overview of the rise of Boston as a sailport provides an example of a port which developed economically for reasons at least partially based upon its suitability for sailing ship navigation. This fact is confirmed below as Boston's initial ability to compete with New York and the advent of the steamship are discussed.

Port Economy and the Advent of Steam

The advantages that steamships brought to marine transport were discussed in Chapter I. In regard to port operations, that type of ship could maneuver more easily under adverse conditions than could a sailing vessel. Assuming sufficient depth of water, a steamship could navigate more freely with less regard to the wind and current (except under severe conditions).[11] After the first crossing of the ROYAL WILLIAM in 1833 (see Chapter I page 26), steamships continued to improve. In 1838, the sailing packets began to feel the competition of steam, and soon the mail, then passengers, and finally the fine freight market was taken over by steamships.

Referring again to Boston, as a sailport, it can be illustrated that its sail orientation, due to physical advantages discussed above, was instrumental in holding back steam competition.

Boston clung to the sailing ship economy longer than would be expected. "In general, the development of steam navigation on Massachusetts Bay was very retarded, owing partly to the lack of sheltered waters and the relatively dependable prevailing southwesterlies."[12] This phenomenon is of central importance to this investigation, indicating that the changes in the economy of a port did, at least partially, depend upon transition in the mode of water transportation.

Boston's geographical advantage as a sailport was extended into the coastal trade economy as well. According to Bunting, "Boston was an important coastal sail port for as long as sail survived."[13] Not until 1894 did steam tonnage exceed sail tonnage in the coastal trades.[14] Just six years later, only about one quarter of the ships entering Boston in the European trade depended upon sail.[15] But, sail remained popular in the coastal trade, and seven years later, in 1907, it still accounted for 39 percent of total coastwise tonnage.[16]

Regardless of Boston's favorable location for sail navigation, the economic development of New York overshadowed Boston. The rise of the port of New York is seen as a twofold process. One aspect concerned activities taking place inland and the other was brought about by changes in the shipping industry. The former centered around the completion of the Erie Canal from Albany to Buffalo in 1825, which opened up a vast inland trade area for the city. The building of the railroads also accommodated the growth of New York and contributed to Boston's decline. America was turning toward its vast interior, and this westward movement left Boston isolated. Her commercial base was threatened by ports nearer the interior, such as Philadelphia, Baltimore, New Orleans, and, of course, New York. "By 1860 the foreign commerce of New York was nearly six times that of all New England" and ". . . most of the nation had become

the hinterland of New York."[17] Cellineri emphasizes this point by stating "New York was emerging as one of the great international ports because it was able to corner the distribution of imports and exports for a national market area."[18]

One must look seaward to see the other process by which Boston fell behind New York. In 1818 the Black Ball Line announced scheduled sailings of its four "packet" ships between New York and Liverpool. For the next twenty years the latest news, passengers, and the most valuable cargoes enjoyed this service. Again, New York took the advantage from Boston. The latter port was frustrated in three attempts to establish an ocean packet service, due mainly to a shortage of eastbound cargoes.[19] So, by the end of the sailing ship era, "Sailing ships had so well secured New York's supremacy that steamships were bound to accommodate themselves to it."[20]

The above trends are confirmed when comparing tonnage of ships registered in New York and Boston in 1829 and in 1860.[21] In that period New York's ship tonnage (total tonnage of ships registered, enrolled, or licensed in that port) increased by a factor of 5.6. Boston's tonnage only increased by a factor of 3.2. In 1829, 100 percent of Boston's ships were sail-powered, while 95 percent of New York's were sail. By 1860, Boston still reported 98 percent of its ships as sail-powered, while New York's figure dropped to 87 percent. The rise of New York as the leading port can be

demonstrated in similar comparisons with Philadelphia and Baltimore.

The growth of New York port has continued with a concurrent increase in congestion and coordination problems. In 1976 New York handled approximately seven percent of all U.S. exports and imports by weight, more than any other U.S. port.[22] Problems of size developed during World War I, and The Port of New York Authority was created by interstate compact between New York and New Jersey to develop a more rational pattern of development and operation.[23] The volume of trade simply became too great for Manhattan and spilled over to Hoboken. Today, the entire area is well described as a "superport," or "load-center."

The emergence of this and other load centers, coupled with the increasing specialization of ships and cargo handling equipment, has acted as a multiplier effect for further growth. "Because of their efficiency, these load centers can attract traffic from ever-widening hinterlands and from less competitive ports on the same and other coasts."[24] Specialized ships, such as containerships, amplify this condition. They are expensive and maintain their competitive advantage by confining operations to few, highly automated ports.

Thus cargo is concentrated at few ports. New York and Rotterdam (Europoort) are two notable examples of this phenomenon. The result is the "functional, technological, and

locational obsolescence of many older and traditional ports."[25] All this takes place under the auspices of good economics. However, the decline of the obsolete ports is somehow shrugged off or ignored. This may be good economics for the fortunate few, but can prove disadvantageous on a regional, national, or world level.

The role of the modern wind-powered cargo ship in reversing this trend toward gigantism of seaports is introduced below.

Revitalization of Sailports

The process whereby certain seaports become dominant over others on the same coast, or in the near vicinity, was explained in the preceding section. Although some individual shippers, port administrators and economists may view this as the inevitable and worthy goal of the economic system, the formidable energy concerns facing the world may force a change. The world's economy is almost wholly oriented to a high consumption of fossil fuels, which simply won't last forever. The shift from petroleum to coal may extend the availability of energy, but the final result will be the foolish destruction of the landscape and further pollution of the global environment. A more rational, energy conservative attitude must permeate society to avoid chaotic collapse in the future. Increased use of wind and solar power are partial answers.

A proliferation of sailing cargo vessels in the size categories under 50,000 DWT would allow increased activity in and the economic revitalization of smaller seaports, many of which are potential sailports. This will require a change in the attitudes of shippers, shipowners, port administrators, governments, bankers, and transport organizers. Admittedly, this change will not come easily:

> The resistance to change embodied in the mechanism of international trade is illustrated by the continued dominance of the port of New York in the handling of internationally traded goods moving to and from the Midwest of the United States long after the historical reasons for this supremacy have disappeared and despite today's [circa 1967] lower inland freight rates to such excellent Atlantic ports as Baltimore and Philadelphia. The same type of inertia is partly responsible for the delay being experienced by the St. Lawrence Seaway in realizing the potential earlier predicted for it. In each case much time is required for exporting and importing firms to become fully aware of changed conditions, for service agencies to be established, and for ocean carriers to alter their routes.[26]

These firms have certainly "become fully aware of" the changes brought about by the present, continuing upward spiral of fuel prices. The complete loss of foreign oil, not an impossible occurrence, will come with the subtlety of a sledge hammer. Now is the time to be aware of potential blows to the economy, whether in the form of contrived political circumstances or simply a depletion of oil. The development of wind-powered cargo ships and their associated port economy today is an investment in the future.

A decentralization of trade-routing to include many smaller ports is particularly germane to the east coast of the United States. Economic revival would enhance not only the larger ports such as Boston, Philadelphia, Baltimore, and Norfolk, but many smaller ports as well, such as Portland, Glouchester, Salem, Bridgeport, New Haven, New London, Charleston, and Savannah. Direct service to these ports by sail would virtually eliminate the added cost of goods due to inland transportation from larger ports by truck. Customary quick delivery may have to be sacrificed, but there will be many sacrifices in the new energy consciousness into which society must embark.

One could suggest the alternative of enlarging and modernizing facilities of smaller ports to meet the demands of larger ships. Once again, this is energy intensive and costly. "Deepening and widening the channels, approaches, and anchorages at all major ports in the United States would be both physically impracticable and financially prohibitive."[27] Sailing bulk carriers of 15,000 DWT will have an average full-load draft of approximately 30 feet, while those of 45,000 DWT will generally not exceed 37 feet in draft.[28] These drafts are compatible with channel and berth water depths in many small seaports. Water depths of the east coast U.S. ports listed above are illustrated in Table 4. Most bulkers of 100,000 DWT have a draft of greater than 50 feet and the draft of some supertankers exceeds 90 feet.[29]

TABLE 4

WATER DEPTHS OF CHANNELS TO
REPRESENTATIVE U.S. EAST COAST PORTS

Port	Channel Depth (Feet)
Baltimore, MD	39
Boston, MA	38
Bridgeport, CN	35
Charleston, SC	35
Hampton Roads, VA	40
New Haven, CN	35
New London, CN	33
Philadelphia, PA	39
Providence, RI	36
Savannah, GA	36

Source: U.S. Army Corps of Engineers, Port Series No. 3 for each port, as appropriate.

These vessels are restricted to very few ports and offshore terminals.

Another alternative to revitalization of the so-called sailports is the development of new port facilities for sail or conventionally powered ships. Congestion at the load centers may prompt some to advocate this response. New construction at the world's already fragile,overused, and threatened coastal areas would constitute disaster. Environmentalists, sportsmen, yachtsmen, and fishermen would undoubtedly, and rightly, oppose this alternative. In any case, the time involved in environmental impact statements, litigation, and funding would be prohibitive. This further supports the proposal for revitalizing existing ports simply by supporting a large scale reintroduction of relatively small wind-powered ships.

There are many favorable environic consequences, as well as economic advantages, of small port revitalization by this means. Relatively small seaports, which are delightful in themselves, could experience an economic revival with little physical change. A suspected migration of the U.S. population toward the coasts, particularly in the warmer regions, will undoubtedly be confirmed by the U.S. Census of 1980. Since this movement is probably already underway, local critics of population influx cannot point to this proposed revival of sail as increasing maritime population density. It will simply help to remove the

strain of unemployment.

Sailing vessels, even those of modern design, will recapture a traditional seafaring spirit that once characterized these ports. This will be entirely compatible with the movement toward waterfront historic restoration so prevalent in many U.S. ports today.

In summary, an opportunity of tremendous potential exists in the synthesis of modern wind-powered cargo ships with small, economically faltering seaports, not only in the U.S., but throughout the world. This proposal may be counter to the prevailing economic trends, but the world's energy situation will undoubtedly force many new trends in the future. Perceptive shipowners, as well as others involved in maritime transport, realizing the potential of wind power can and must act now to herald the new age of energy consciousness.

Shipbuilding and Repair

The impact of a large number of sailing cargo ship orders on the world's ailing shipbuilding industry could be the long awaited stimulus necessary to revive that industry economically. According to a U.S. Maritime Administration Study for calendar year 1979, seven of the fourteen major commercial shipyards in the U.S. lacked a sufficient backlog of orders as of December 31, 1979 to justify their available facilities and manpower.[30] "With the expected decline in

orders for commercial ships, several major yards face possible mass layoffs."[31] This slump in shipbuilding is not just a U.S. problem. The Royal Institution of Naval Architects, in its official journal, quotes a Lloyd's spokesmen who predicts that half of the world's shipbuilding industry will not survive.[32]

A significant reason for the decline of shipbuilding in the U.S. is the high costs involved compared with building in other countries. A foreign shipyard can build ships at an average of 40 percent of the U.S. cost.[33] Additionally, ship orders from U.S. firms, regardless of the country in which the ship is built, are down because of the lack of a sound governmental policy which backs U.S. shipping.

Reasons for the worldwide shipbuilding decline are similar to those that the United States faces. The established shipbuilding countries are part of the "developed" world. Shipyards in the third world nations underbid even the Japanese, who were the longstanding leaders in the industry. "Third world shipbuilding power has increased its output seven-fold during 1976 and has managed to capture 16 percent of the world order book compared with 6% in 1974, seriously threatening the future of shipyards in established shipbuilding countries."[34]

The investment potential inherent in a building program of several sailing bulk carriers was discussed in Chapter III. If the ships are built in U.S. shipyards, this potential

spills over into that industry. The recent legislation favoring bulk carriers, also referred to in Chapter III, reinforces the likelihood of a turnaround in the U.S. shipbuilding economy. Because these modern sailing ships will be of smaller average size than many of the large bulkers built in recent years, smaller shipyards may be the primary beneficiaries of this positive economic trend.

Shipbuilding and repair is in essence an industrial activity. For this reason, it will be received with mixed emotion among littoral inhabitants. These activities will generate jobs and revenue, but they will also bring noise and other forms of industrial pollution. However, the emergence of small scale activities which produce smaller vessels of a size advocated herein will undoubtedly have a most favorable impact. This is based on the inherent fascination of people for "things of the sea." A boatyard, where boats or small ships are built and repaired has an undeniable and unidentifiable aesthetic attraction for a great many people. This is confirmed partially by the popularity of these sites as subjects for artists and photographers. A boatyard certainly presents a more pleasing site to the majority than does a car repair garage.

The consideration of ship hulks expands this argument even further. A wreck or hulk, even if encased in rust, or ravaged by decay, has what may be described as an aesthetic aura. It will invoke thoughts of adventure and travel to

far away places. This sense of mystery will capture the imagination of those who pass, as they ponder the craft's final demise in its last resting place.

A strikingly different response is evoked by a wrecked car, or truck or a junkyard filled with car "hulks." There is nothing positively stirring in a wrecked and rusted automobile or truck abandoned along a street curb. One wonders not about the journeys of that vehicle along the nation's highways and streets, but only when it will be towed away. It is a blight, an insult to one's senses, and has no aesthetic qualities.

Similarly, a yacht basin, or a harbor filled with fishing boats, triggers a more pleasing reaction than does a car parking lot.

This enthrallment with ships and boats is perhaps an extension of man's fascination with the sea. The suspected migration toward the coasts is an indication of this phenomenon. This movement may prove beneficial toward an effort to reintroduce large numbers of relatively small sailing cargo vessels. A large labor market may be created that simply can find nothing else to do. Shipbuilding, now in a slump, will boom. Creative skills which disappear or lose perspective in large shipyards where giant ships are built, are certain to enjoy a revival. People attuned to ships and the sea will be needed to build and sail them. Thus, the association of water and wind will offer an

economic stimulus to ports, coastal towns and villages and their shipping and shipbuilding industries.

TRADE ROUTING

A motor-powered merchant ship will generally proceed between ports on as direct a route as possible (deviations to this "shortest distance" route based upon weather routing are discussed in Chapter V). Some sailing ship routes will be similar, assuming favorable following winds, but other sailing routes will be longer, to include zones of favorable winds for the route in question. For instance, sailing vessels on the historic route from Europe westward to the east coast of the U.S. often sailed far to the south to take advantage of the northeast trade winds. However, vessels proceeding from the U.S. (Boston or New York, for example) traveled a near straight line route to Europe in the zone of the prevailing westerlies. Figures 20 and 21 illustrate wind zones and sailing routes, respectively on a world-wide basis. In many cases, modern sailing routes will differ from traditional steamship routes for this reason. A sailing ship will often sail more miles than a steamship for a given route. The sailing vessel will undoubtedly experience a longer passage time by virtue of this fact, as well as because of its inherent lower speed. However, as discussed in Chapter III, many trades exist where consistency of delivery is more important than speed of individual passages.

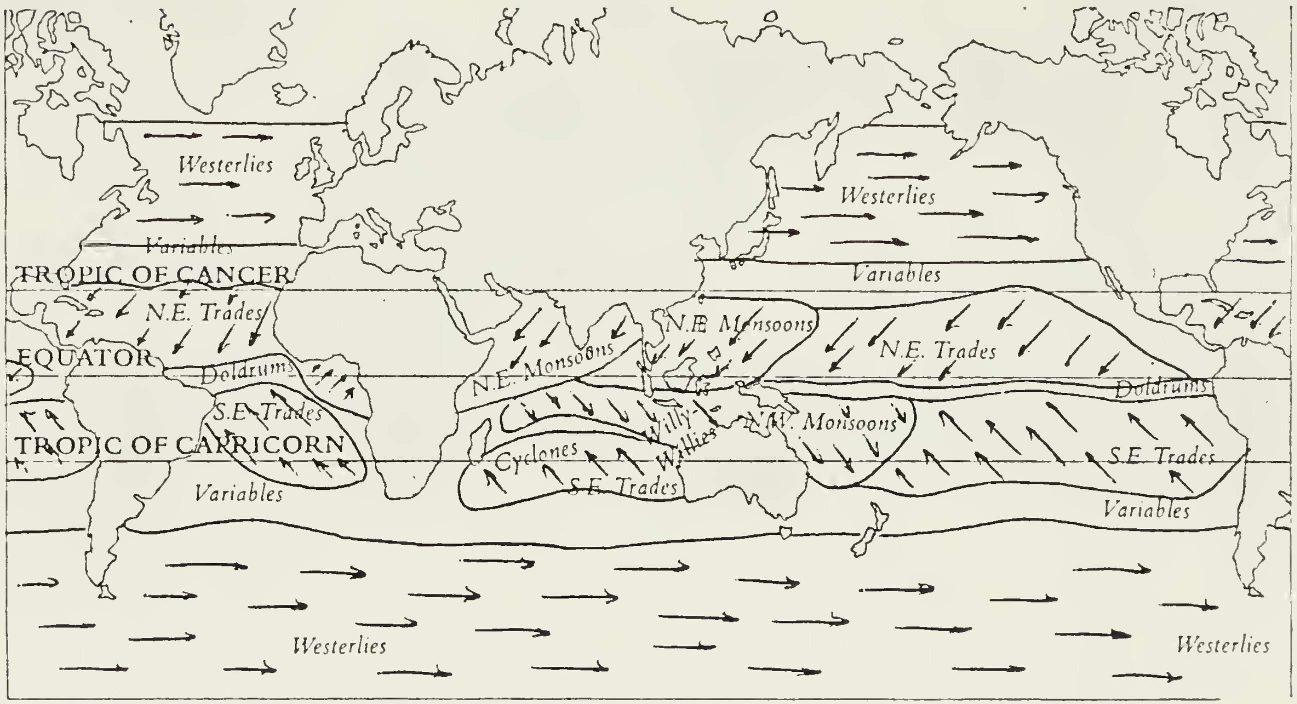

FIGURE 20a. World Wind Patterns: January-March

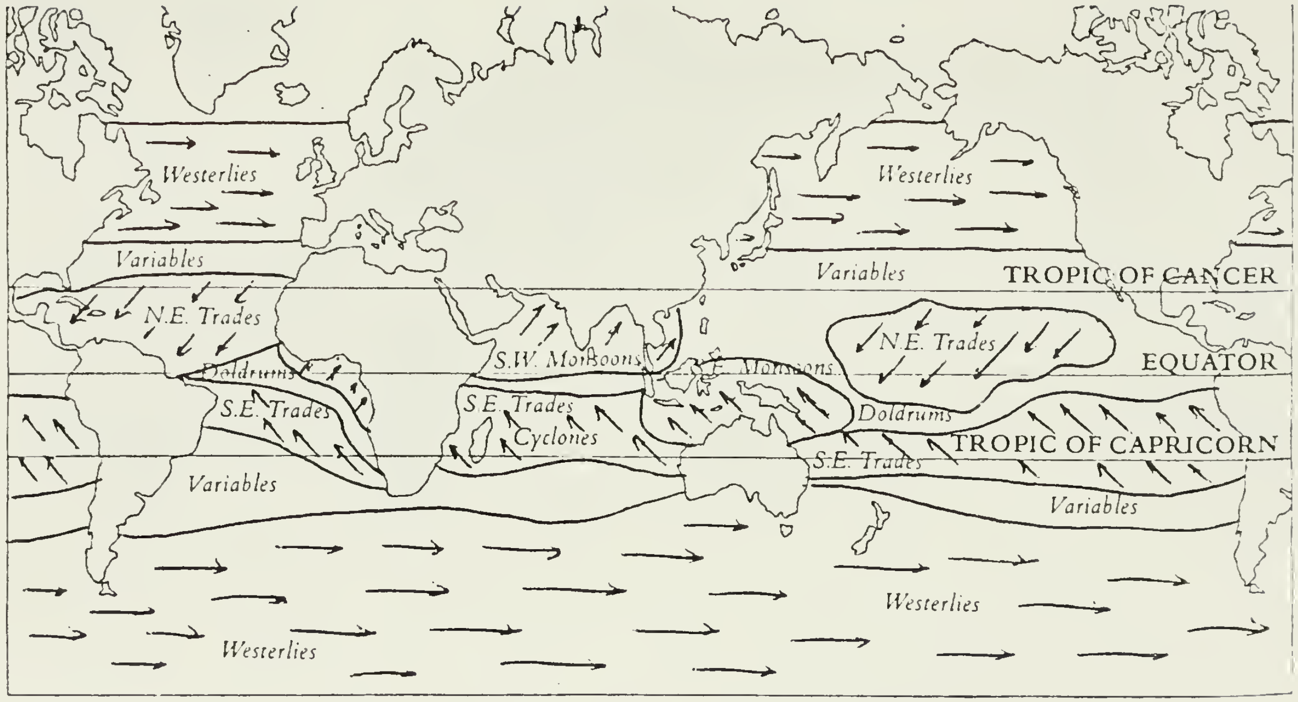

FIGURE 20b. World Wind Patterns: April-June

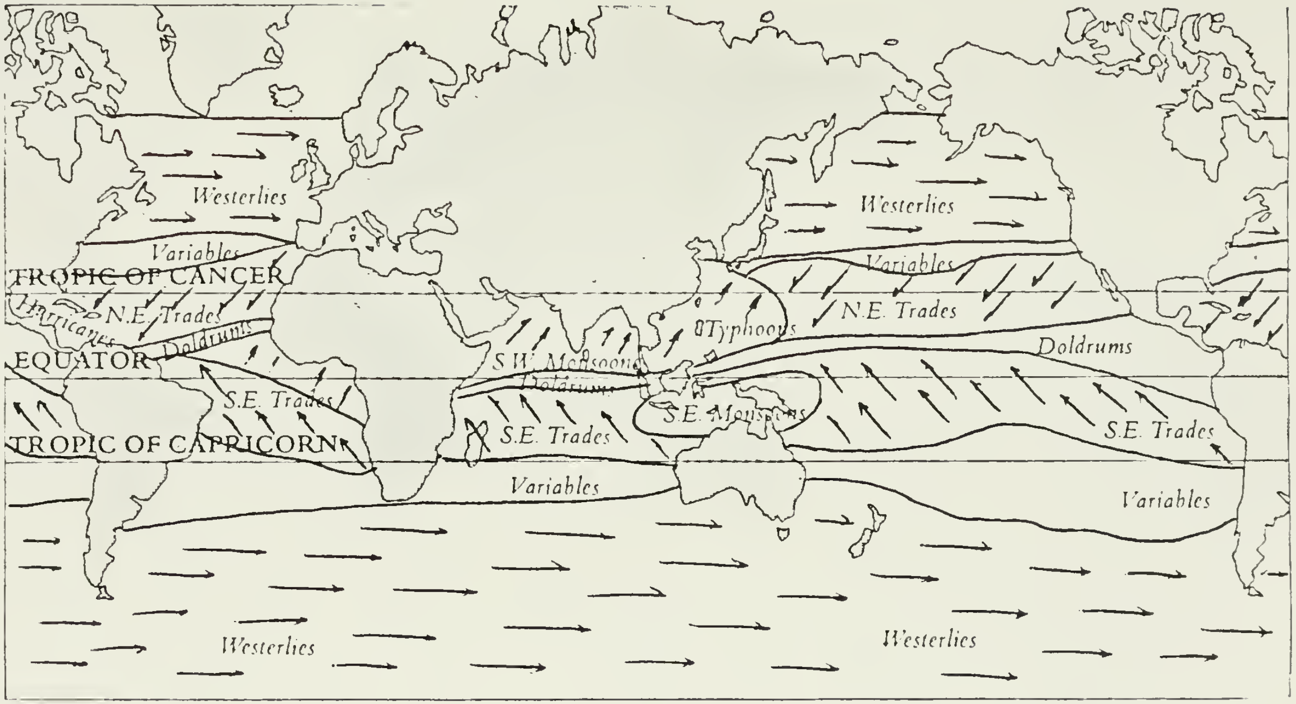

FIGURE 20c. World Wind Patterns: July-September

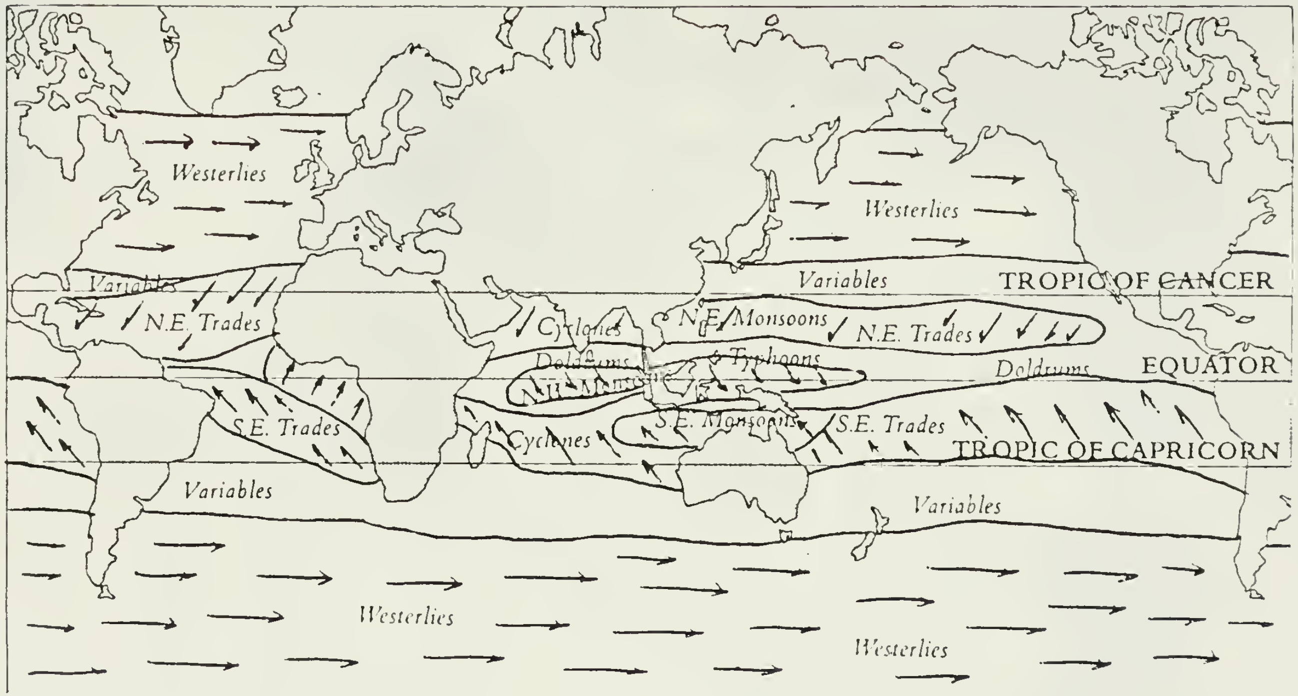

FIGURE 20 d. World Wind Patterns: October-December
Source: The Visual Encyclopedia of Nautical Terms Under Sail, (New York, 1978), Subsection 17.02.

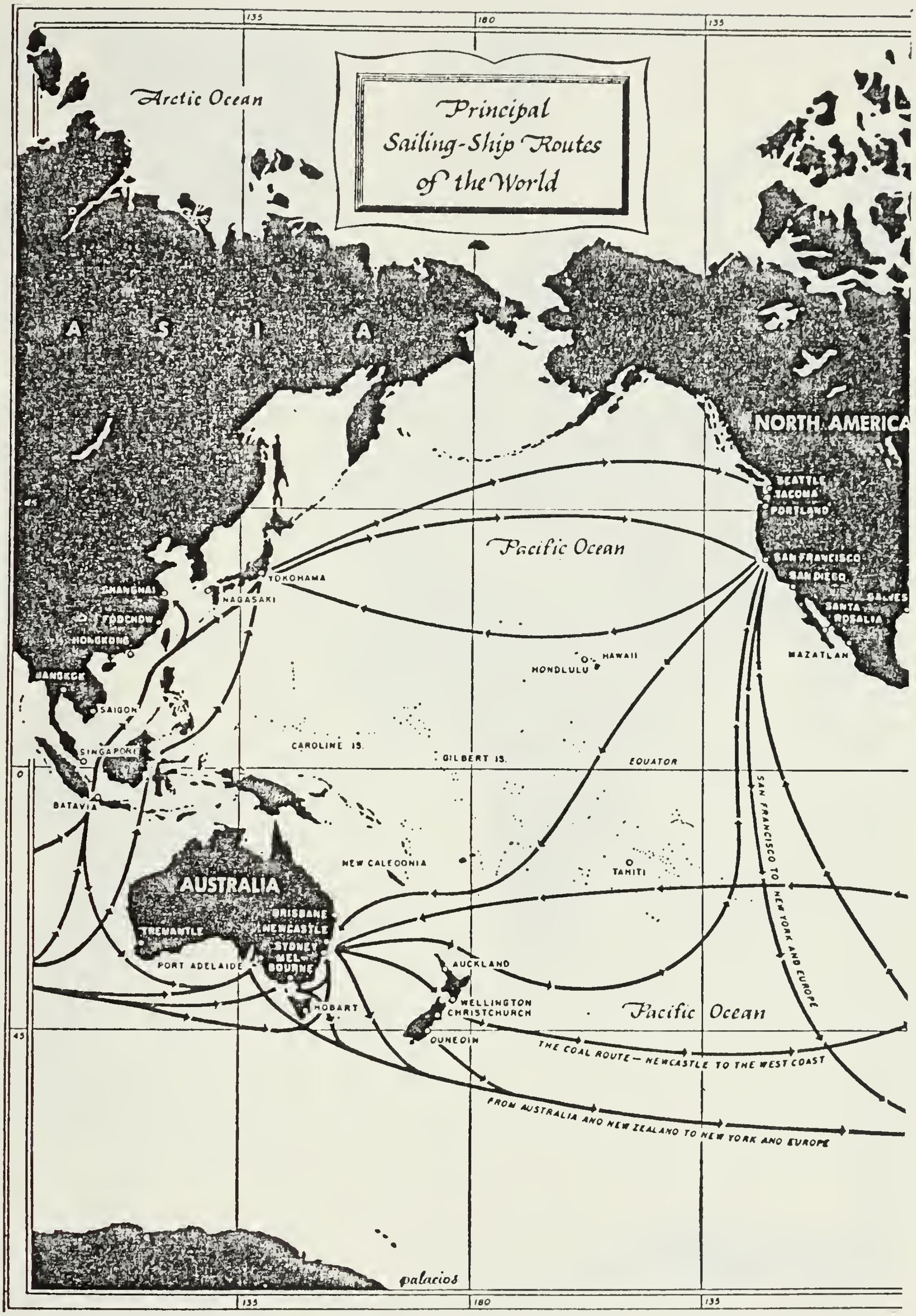

FIGURE 21a. Principal Sailing Ship Routes - Pacific
Source: Alan Villiers, <u>The Way Of A Ship</u>, p. 414.

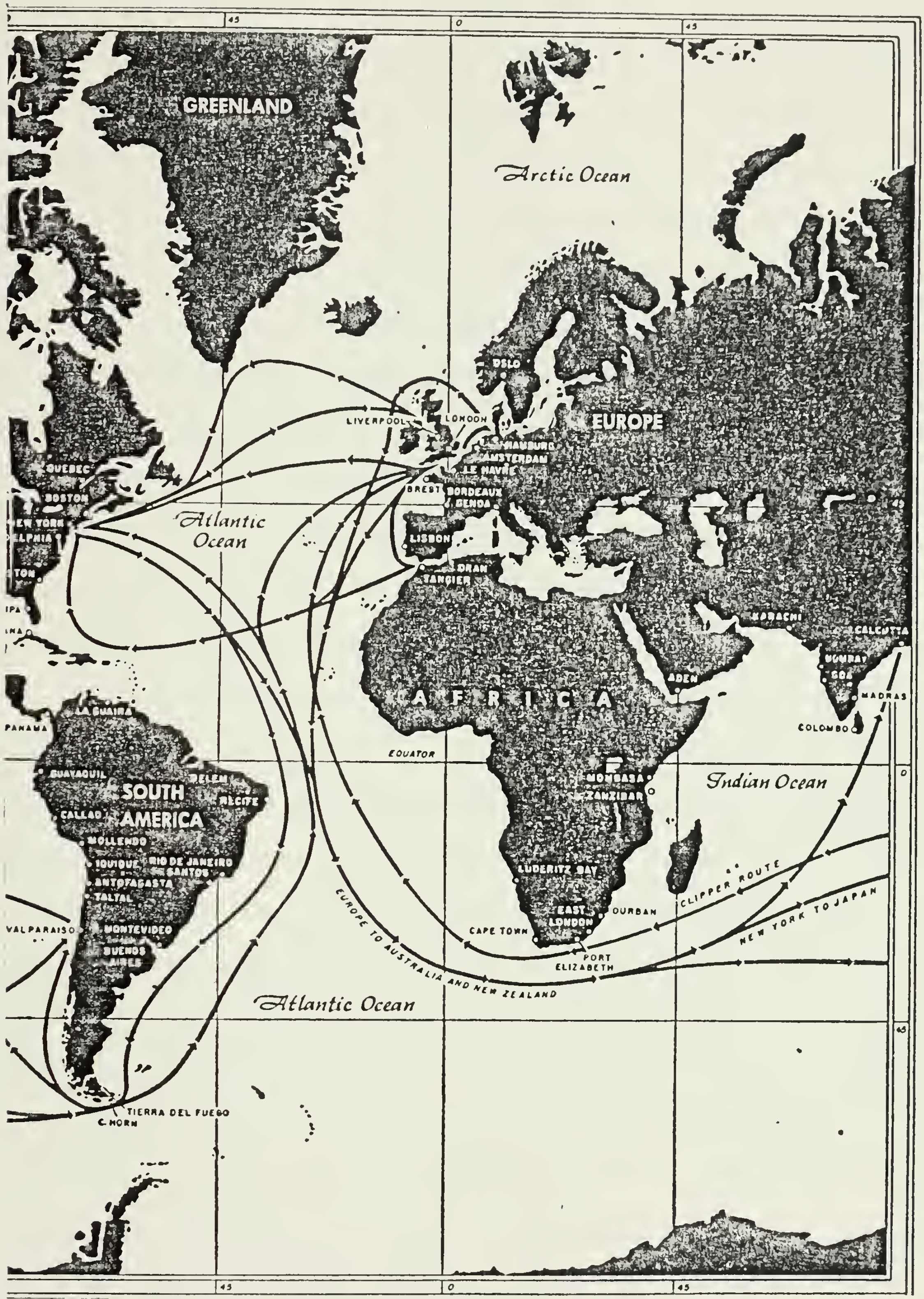

FIGURE 21b. Principle Sailing Ship Routes - Atlantic and Indian Ocean
Source: Alan Villiers, The Way Of A Ship, p. 415.

In order to illustrate this trade routing, three routes are chosen from U.S. to foreign ports. The routes are: U.S. North Atlantic ports to United Kingdom and Europe (Figure 22), U.S. Gulf ports to United Kingdom and Europe (Figure 23), and U.S. Pacific ports to the Far East (Figure 24). These routes have been designated as essential United States foreign trade routes by the Maritime Administration.[30] The three routes chosen indicate those with the highest amounts of commodities (in tons) imported and exported per year. Each of the routes also includes significant trade in bulk materials suitable for modern wind-powered cargo ships.

For the purposes of this discussion, specific ports have been chosen to illustrate the differences in trade routing of sailing vessels and motorized vessels. These are Boston to Le Havre (U.S. North Atlantic to U.K. and Europe), New Orleans to Le Havre (U.S. Gulf to U.K. and Europe), and Seattle to Yokohama (U.S. Pacific Coast to the Far East). Comparisons in routing for the two different types of ships are shown in figures 25 through 27. Table 5 shows the differences in miles traveled on the particular routes described. In each case the sailing vessel track makes maximum use of prevailing winds. No speed or time comparisons are made here due to the potential variety of ship's size, type, rig and speed, as well as the case-by-case application of weather routings.

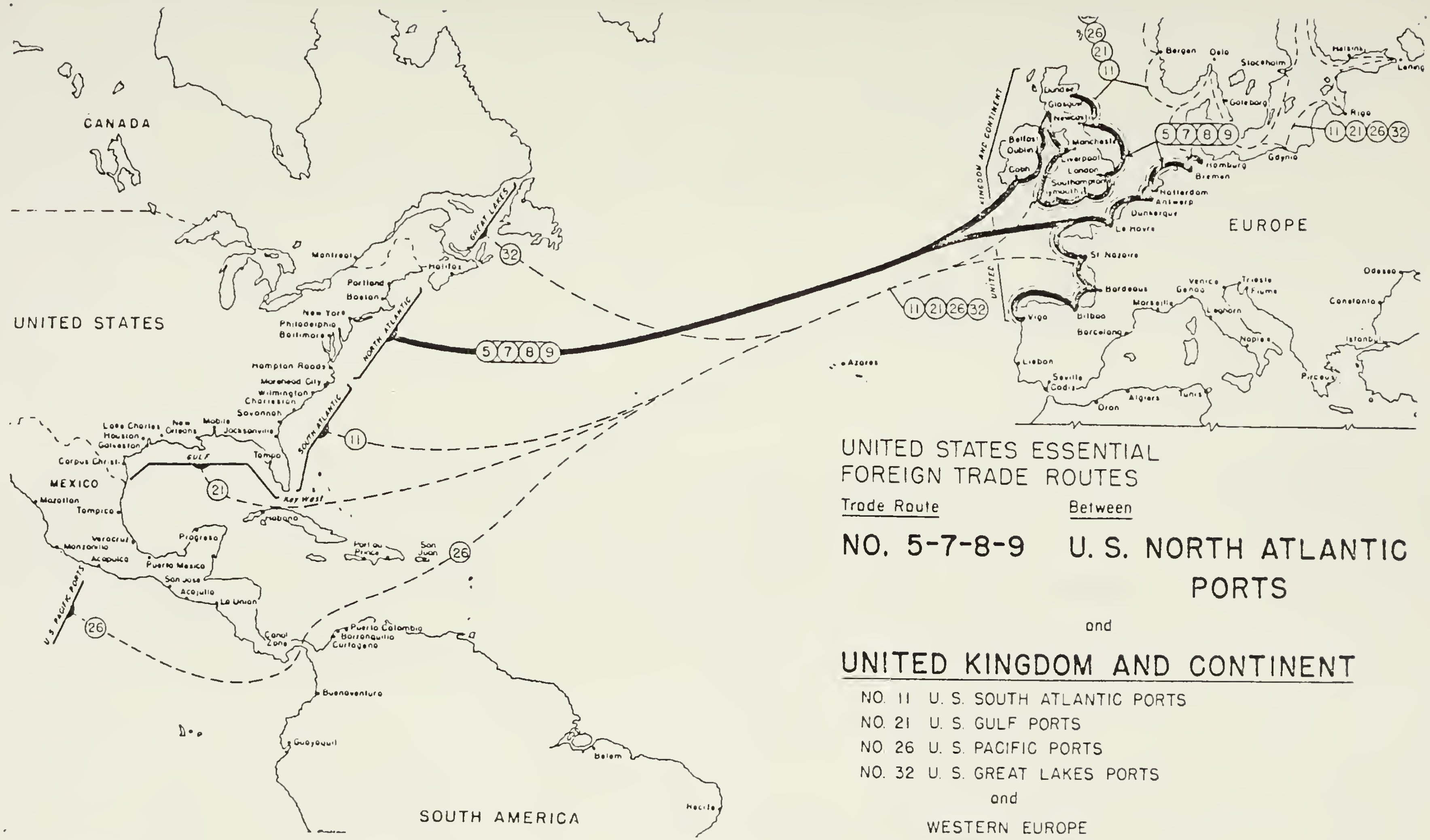

FIGURE 22.
Source: U.S. Department of Commerce, Maritime Administration, Essential United States Foreign Trade Routes, June, 1975, p. 16.

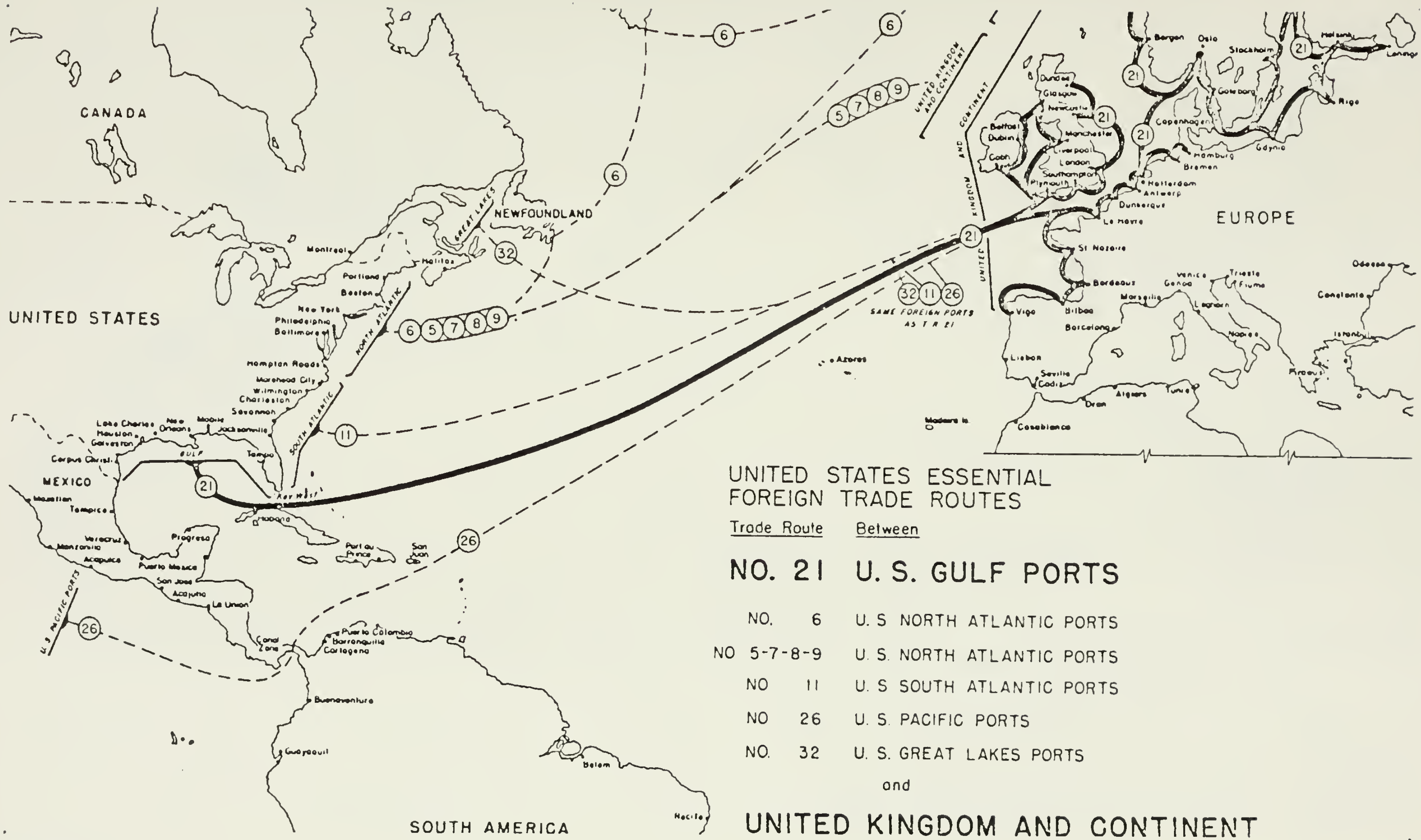

FIGURE 23.
Source: U.S. Department of Commerce, Maritime Administration, Essential United States Foreign Trade Routes, June, 1975, p. 44.

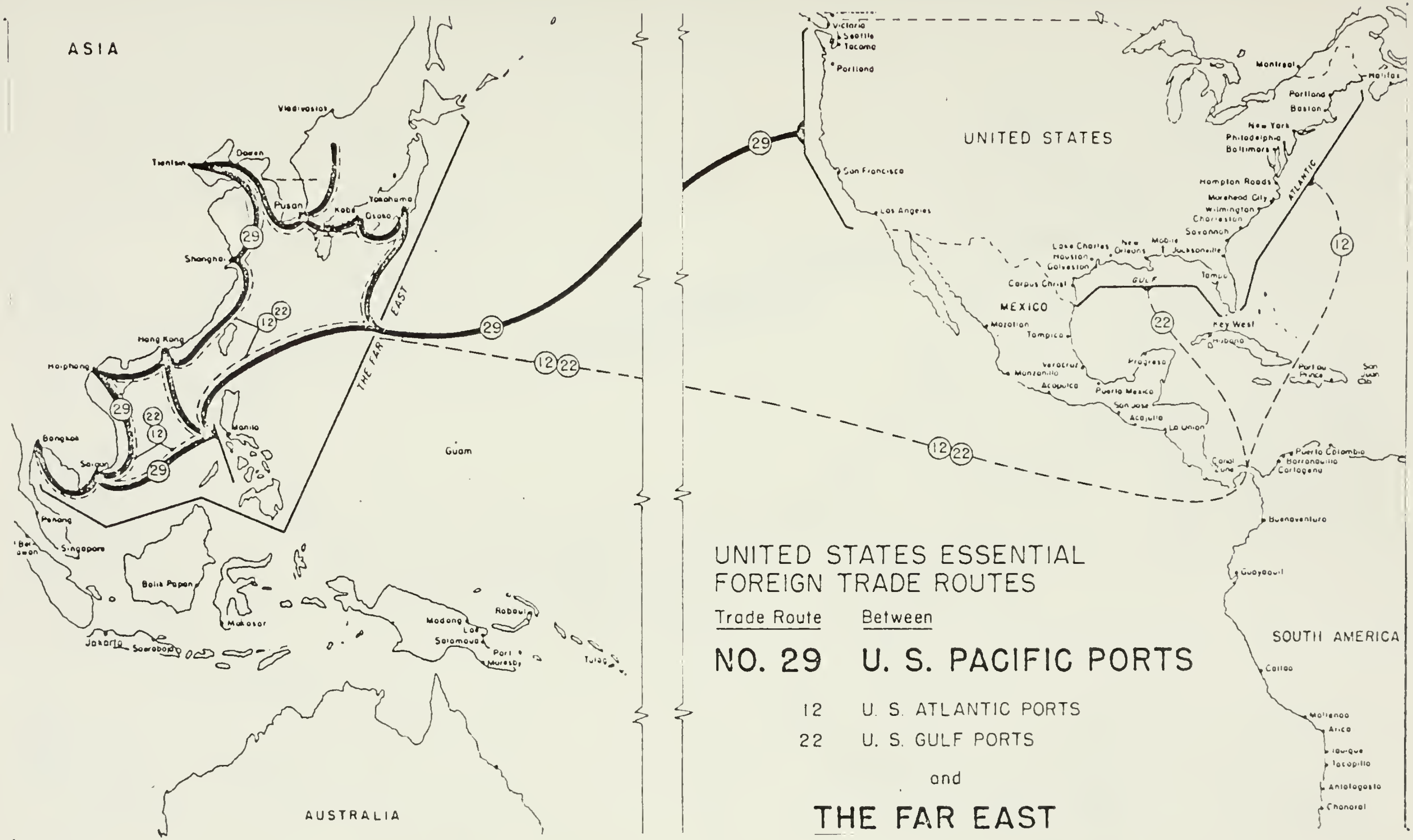

FIGURE 24.
Source: U.S. Department of Commerce, Maritime Administration, Essential United States Foreign Trade Routes, June, 1975, p. 60.

FIGURE 25. Comparison of Sailing and Motorized Ship Routes Boston-Le Havre

FIGURE 26. Comparison of Sailing and Motorized Ship Routes New Orleans-Le Havre

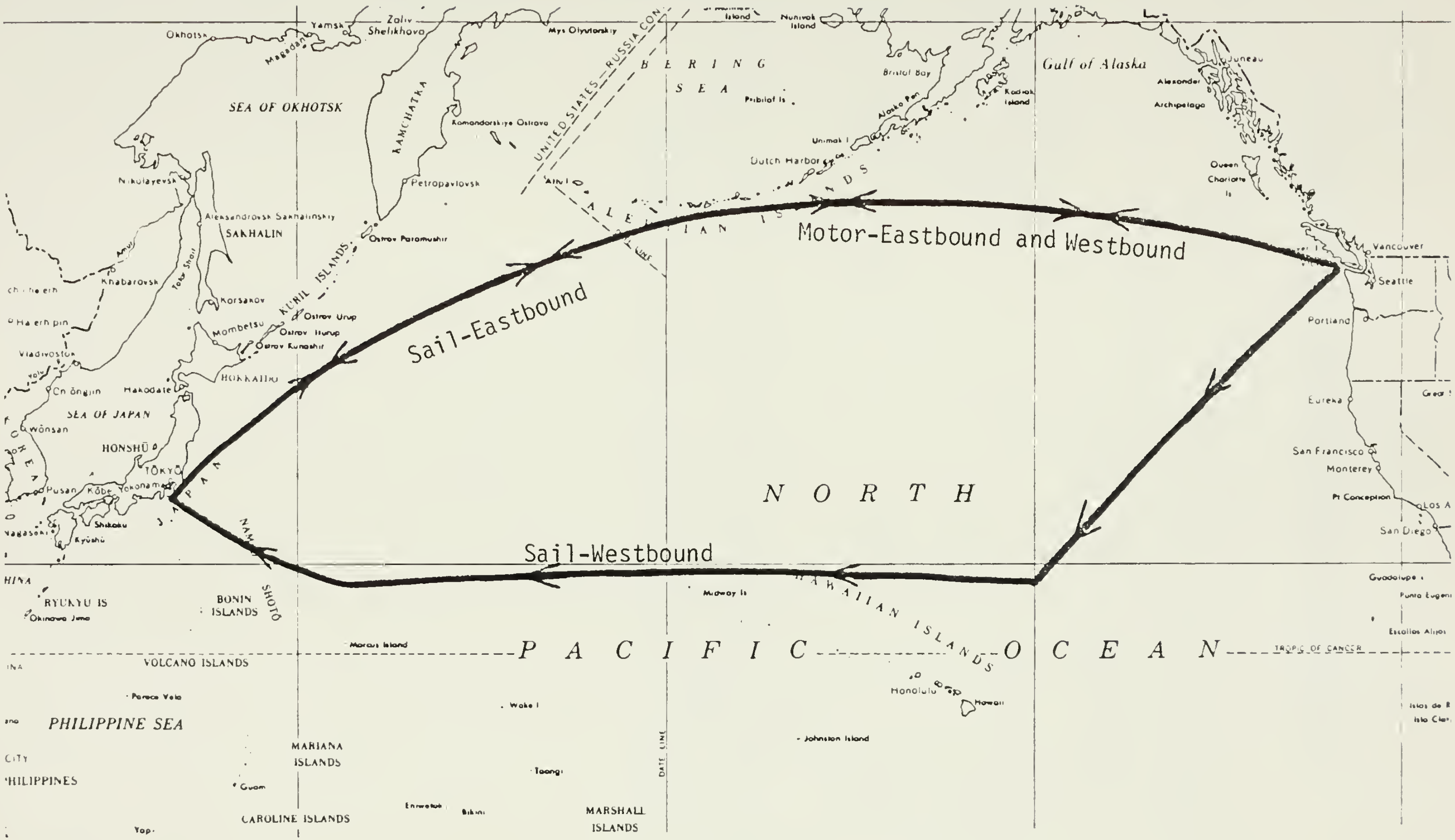

FIGURE 27. Comparison of Sailing and Motorized Ship Routes Seattle-Yokohama

TABLE 5

COMPARATIVE DISTANCES BETWEEN SELECTED PORTS FOR MOTORIZED SHIPS AND SAILING SHIPS

Route	Distance, Nautical Miles[a]	
	Motorized	Sailing
Yokohama-Seattle	4276	4276
Seattle-Yokohama	4257	4980
Boston-Le Havre	3070	3070
LeHavre-Boston	3070	4810
New Orleans-Le Havre	4559	4559
LeHavre-New Orleans	4559	5300

[a]Distances reflect direct, average optimum routes. Actual distances would vary depending upon weather routing to obtain optimum conditions for the local weather situation.

Source: Pilot Charts of the North Atlantic and North Pacific Oceans, June, 1980, Defense Mapping Agency Hydrographic/Topographic Center, Washington, D.C.

Similar comparisons can be made for any designated trade routes throughout the world to show the comparison between sailing ship and motorized ship routing. It must be emphasized, however, that these are general routes based on average wind conditions. Actual voyages, based upon more detailed seasonal weather charts and weather routing, may vary considerably from those shown here.

Another aspect of trade routing in which sail can take an important part is coastal or inter-island trade. Most of the coastal areas of the populous world regions, as well as most of the inhabited islands, are located in the zones of the westerlies, the trade winds, or the monsoons. As a result, dependable winds blow consistently. It is in these trades where commercial sail may first begin on a large scale. Smaller vessels with fore-and-aft rigs will most likely be the progenitors of modern sail. These ships will have schooner-type rigs, a rig well suited to coastal trade (see Chapter I, page 24).

SHIP/LAND INTERFACE

Maritime transport is fundamentally an employment of ships at sea. A vessel underway, laden with cargo, is a viable economic asset. That same vessel in port, discharging and loading its cargo, or lying-to in a channel awaiting berthing space is an economic liability. A shipper's objective is maximum "underway" time for his vessels, for then he earns money. Port operations, repairs, and idleness are expensive, although unavoidable.

Ship design has a dual application. A vessel is designed and built for efficient interaction with her primary element the sea. Conversely, the ship's interface with the land is also a consideration of primary environic significance. It is the latter case which imposes restrictions on the designer such as draft, length, maneuverability, ease of cargo handling, compatibility with piers and quays, and personnel safety during dockside operations. Good ship design minimizes expensive in port operations and enhances profitability.

Ship specialization has engendered similar evolution of in port cargo handling operations. This has led to increased cargo handling efficiency, which experienced a five-fold increase in productivity (tons of cargo handled per longshore hour) between 1967 and 1977.[36] New vessels must conform to these systems, generate their own ship/land interface, or fail.

Modern wind-powered cargo ships introduce new challenges into this relationship between ships and ports. In the last era of sail, cargo handling operations were slow, and were expected and accepted as so. The advent of steam and the concomitant fascination with speed signalled the evolution of efficient port operations. Modern sailing ships will be thrust into an environment in which they will be considered an anomaly. Proof of their viability will depend upon the imaginative handling of these problems by their designers.

In-Port Maneuverability

The assumption is made that modern sailing ships will employ auxiliary engines at some point during their approach to a port. A second important assumption is that the vessels are equipped with adequate auxiliary power to overcome reasonable forces of current and wind. The latter is of special importance due to the added wind resistance of the masts or other wind propulsion devices. In addition, tugs are normally available to assist any ship in port. Many newer vessels are equipped with bow thrusters[37] to enhance import maneuverability. These were proposed on several of the designs for sailing ships discussed in Chapter II.

In view of the above, maneuverability of sailing ships in port should be equal to that of motorized ships. As discussed in Chapter III, page 119 sailing ships under

auxiliary power are, in a legal sense, motor-driven vessels. Full compatibility of modern wind-powered ships with existing requirements of maneuverability is anticipated.

A related consideration of sailing vessels is the height of rig. This is projected to be as high as 206 feet for a Dynaship of 35,000 DWT. Bridge clearance in some ports may therefore exclude large wind-powered ships. A representative list of bridge clearance is shown in Table 6. Designed height of rig will be an important consideration for vessels intending to trade in ports where bridge clearance is restrictive.

Cargo Handling

A wind-powered ship with masts and rigging or other wind propulsion devices may cause problems of incompatibility with modern cargo handling equipment. Swinging cranes or rail-mounted loaders/unloaders which sweep along the deck to gain access to each cargo hatch are fraught with disadvantages. Cranes, either shipborne or shore-mounted, will have limited application for handling break-bulk[38] cargoes. Windrose Ships, Ltd. and Ocean Carriers Corporation are contemplating use of such shipborne cranes.[39,40] Dynaship Corporation, anticipating interference during cargo handling, has designed a feature whereby the lower yardarms fold upward against the masts during port operations.[41]

Modern wind-powered ships designed for the bulk trades

TABLE 6

VERTICAL CLEARANCE FOR BRIDGES OVER SELECTED U.S. WATERWAYS

Waterway and Bridge	Vertical Clearance (Feet)
Chesapeake Bay	
Wm. P. Lane Memorial Bridge	187
Columbia River	
Astoria, Washington Bridge	205
Narragansett Bay	
Newport Bridge	194
Thames River (New London, CN)	200
New York Harbor	
George Washington Bridge	213
Verrazano Narrows Bridge	232
Delaware River (Philadelphia, PA)	
Delaware Memorial Bridge	188
Walt Whitman Bridge	150
Benjamin Franklin Bridge	135
San Diego Bay	
San Diego-Coronado Bay Bridge	195
San Francisco Bay	
Golden Gate Bridge	232
Oakland Bay Bridge	221

Source: U.S. Army Corps of Engineers, Port Series No. 3 for each port, as appropriate.

are likely to be more compatible with cargo handling systems. Lighter bulk materials, such as grains and grain-meal, are suited to pneumatic loaders and unloaders. Several systems are in existence or under construction for conventional ships[42] which appear compatible with sailing ships. Pneumatic systems positioned over the hatches and lowered into the holds are carried on pivoting and/or telescoping booms which can easily be maneuvered around a ship's masts. This will not be an unusual phenomenon, as many motorized ships are equipped with masts and booms. In anticipation of modern sailing vessels taking a share of maritime transport, designers of cargo handling systems should ensure compatibility of future equipment with both sail and motor-powered ships.

In anticipation of service to smaller ports with less cargo handling facilities, both in degree of sophistication as well as quantity, sailing ship designers should focus on development of shipborne equipment. This is particularly true with smaller ships which are likely to participate in the break-bulk market. In this way these ships can assist in the revitalization of maritime transport economies and minimize the huge capital investment necessary for modern shoreside cargo handling equipment.

A recent test using a helium balloon to offload containers for ship to shore movement is next discussed as a logical complement to wind-powered ship operations. The

test was sponsored jointly by the U.S. Army and U.S. Navy in 1976 in an effort to develop a method for unloading a containership for military purposes in areas lacking port facilities.[43]

Should a catastrophic interruption in foreign oil supplies occur, sailing vessels will be in high demand to transport import and export cargoes. Lack of energy may cause a corresponding shutdown of established cargo handling facilities. This balloon system would present a logical alternative for offloading sailing cargo ships. Its independence of port facilities makes it ideal for use in relatively remote coastal areas which may suffer from lack of land transport feeder systems from major ports.

The test was conducted at Fort Story, Georgia during March and April, 1976. A balloon of about 100 foot diameter was used to lift containers loaded with 6,000 pounds of cargo. The balloon was of the type used in the Pacific Northwest for logging operations. A craft simulating a containership was moored 700-800 yards offshore. Supporting equipment included vehicle- and ship-mounted winches to pull the balloon back and forth between ship and shore. The balloon itself provided the lifting force. A complementary test lifting containers from ship to lighterage was also conducted.

The results of these tests were promising. "The balloon has good potential for direct ship-to-shore container

offloading of merchant ships. To a lesser extent the balloon could be employed for ship-to-lighterage container offloading."[44]

Although modern sailing ships are best suited to the bulk trades, their use as containerships is not out of the question. Mr. William Warner of Dynaship Corporation suggests this as a possible employment for ships of his design.[45] Critics will quickly point out the possibility of the masts interferring with and puncturing the balloon. These balloons were developed, however, for logging operations in areas of tall trees and this does not appear to be a problem. During ship loading/unloading operations the balloon would be high above the masts. Positive control of the balloon and rig would be necessary to prevent the containers from making contact with the masts during raising and lowering operations.

Although no cost data were given in the test report, it is surmised that this system would be much less costly than a modern container crane, priced at $2.5 million in 1980.[46]

In summary of the above issues concerning the ship/land interface, the specialization of ships and cargo handling facilities confirms the need for cargo handling standardization on an international basis. This has been recognized only recently (1951) with the establishment of the International Cargo Handling Coordination Association (ICHCA) in Great Britain.[47] This organization was founded by Rear Admiral Alexander L.P. Wardlaw and Rene Courau as a logical

means of facilitating the land interface of maritime transport, which, by its very essence, is international. The essential requirement for continued coordination in the light of the reemergence of sail is discussed below.

Impact of Sail

A large scale return to sail power will have a substantial impact on port facilities, as discussed above. Planning in this regard, however, will undoubtedly await the introduction and successful operation of these vessels. Hopefully, imaginative foresight will preclude a lag in port development to accommodate sailing ships. This would only thwart the continued development of wind-powered ships. Coordination of shoreside activities with the needs of these ships is imperative.

The ideal instrument for this coordination is the ICHCA, discussed above. Correspondence with this organization confirms, however, that the implications of wind-powered ships have not yet been considered. The Secretary-General of ICHCA states, nevertheless, that "The membership of the Association is always interested in new methods of transport which reduce costs and . . . will examine the implications for cargo handling when the introduction of sail can be shown to be a sound economic proposition."[48]

Similarly, the Port of Rotterdam (Europoort) is awaiting evidence of the advance of wind power technology

for particular shipping. Dr. F.A.F. Scheurleer writes, "Although we always try to follow the developments in shipping, we have not yet spent much time thinking about the implications for the port of a possible significant increase in the number of large cargo-carrying sailing vessels plying the seas," but, "it will be our policy in the future, as it has been in the past, to keep our infrastructure as flexible as possible, so that we will be able at any time to accommodate the vessels our clients would wish to bring into the port."[49]

Successful integration of wind-powered ships into the shipping and cargo handling industries depends upon the sincere application of the principles claimed by those quoted above.

SHIP MANNING

An idea as romantic as that of sailing ships is likely to have enormous emotional appeal. Many respondants to employment offers on modern wind-powered ships will undoubtedly be filled with notions of high adventure. Some will be ideal candidates, others will not. Cargo ships spend long periods at sea and all individuals are not suited to this type of life. Modern sailing ships may very well spend even more time between ports than motorized ships. Many may find this life boring and unrewarding. Others will revel in the life style at sea under sail. A ship owner

will do well to employ the services of professional recruiters to investigate thoroughly the psychological suitability of prospective crew members.

Marine Psychology

Life at sea during the great age of sail has been highly romanticized by books, television and the cinema. In truth, the life was one of extreme hardship, deprivation, discomfort, and sometimes cruelty. Yet, adventurous individuals who chose that life "took a fierce pride in their competence."[50] To many, the sea was "first and foremost a source of employment, a means of livlihood,"[51] and they knew no other life.

Ships such as these no longer exist, nor does the breed who sailed in them. Modern seamen, although still in relatively close relationship with the natural elements, are provided with most basic comforts available to landsmen. Ships supply good food, comfortable quarters, and activities for off-duty entertainment. Most of the physical labor has been supplanted by mechanical devices. Modern wind-powered vessels will conform to these standards and, in fact, will be "modern" in every sense.

The sailing vessels will, however, allow a revitalization of a man-nature relationship that languished with the advent of steam. As ships became larger, this relationship became more impersonal, and in some cases, ceased to exist. Automation and gigantism overshadowed an intimacy with the

sea once felt by those who labored upon it. Even the individuality and personality of ships has diminished as functionalism and economy have replaced the nautical mystique which once seemed to give a ship almost human character. Noel Mostert has described a modern supertanker as "a tank that's been fitted with engines and a place to live in and steer from."[52]

Smaller, wind-powered ships will reawaken these basic environic qualities and attract serious individuals who are well-suited to the sailing ship life. Observation of the ship's interaction with wind, waves, and current will be central to a safe and successful passage. Those individuals attuned to this coexistence with the natural forces will find a deeply satisfying way of life.

Indications are that modern sailing ships will not experience a lack of willing applicants for crew members. Dynaship Corporation has been inundated with inquiries concerning employment opportunities on their ships.[53]

The question of who will command these modern sailing ships is one often asked by those who doubt the concept. Potential ship masters with experience under sail are scarce and becoming more so. That experience is of profound importance in modern sailing ships. It may be argued, on the other hand, that these modern ships exist on a different technological plane than those of the last era of sail, and that past experience has no application. However, regardless of the technological sophistication involved, there is

no substitute for experience in the fundamental environic interaction of wind-powered ships and the natural forces.

The last routine, maritime transport under sail disappeared in the early 1900's. The training ships, nitrate ships and grain carriers were anomalies in a mechanical age. However, these vessels were viewed as a fertile training ground for future officers in steamships. Those trained under sail enjoyed a psychological superiority in seamanship, although the fact was undoubtedly ignored in their pay. At the very least, this conveyed a sense of individual initiative, as a great deal of effort would be spent qualifying under sail. Individuals with these qualities must be sought out to command the first modern wind-powered ships and pass their experience and skills along to the next generation of sailing ship officers.

While the consistency of traditional seamanship under sail has been broken, the popularity of sailing among amateurs has risen phenomenally over the past two decades. This will probably continue, perhaps at a faster rate considering the problems of fuel cost and availability. This may result in the next generation looking toward sail as a means of livlihood.

There are reportedly ship's masters with sail experience in organizations such as the Square-riggers Club and the Council of American Master Mariners.[54]

Sail Training

Operation Sail in 1976 confirmed the maritime nations' current interest in at-sea training under sail. Approximately 100 ships, manned for the most part by young people, sailed across the Atlantic to participate in OPSAIL '76, organized in New York by Frank Braynard. The "training" experienced by the crews of these ships takes three different forms. First, are the training programs which many nations, particularly European, administered to support the requirements for future merchant marine officers. Second, are training programs to prepare prospective officers for a specific service, such as the navy, or in the case of the U.S., the Coast Guard. The remaining category is training for young people who, for various reasons, would never otherwise participate in a wholesome and challenging experience such as that offered on a sailing vessel.

The underlying principles of training young people under sail are the building of character and an appreciation of the importance of teamwork. Villiers has written, "there is no question that the character-building qualities of the small sailing-ship are unrivalled and cannot well be duplicated in power-driven vessels."[55] The value of sail training is well stated by Barclay Warburton, President of the American Sail Training Association:

> Simply put, the Europeans, and particularly the British with their very special maritime

> heritage, seem to quickly recognize that there is still no more efficious way to turn a confused young boy into a purposeful young man than to get him aboard a sailing ship for a period of time ranging anywhere from two weeks to two months. He accepts discipline quickly, because he is in a totally strange environment where he is helpless unless told exactly what to do virtually every minute. He perceives that a sailing ship is so incredibly complicated that it could not possibly work without a high degree of order. And he feels a strong sense of belonging, because even if his job is a most menial one, he can see that the entire structure depends upon each one relying upon the other to do his particular job.[56]

The above principles apply to young women as well as young men.

In addition to the aspects of discipline and teamwork, young people also gain an appreciation for the interaction of man with the forces of nature. Nowhere is this as strikingly evident as at sea in a wind-driven ship.

A synthesis of maritime transport by modern sailing ships with sail training offers significant mutual benefit. Some of the modern sailing vessel concepts discussed in Chapter II have proposed cadet training as part of routine operations. Benefits to the trainees have been discussed above. The shipowner benefits in the short term by a supply of cheap, enthusiastic labor. Long term benefits will be seen in the training of future crew members who will have an appreciation of wind power as a fundamental environic relationship between man and the natural forces.

Modern sailing vessels will incorporate, for basic economic reasons, many labor-saving devices. They will not

offer the same opportunities for training as the traditional full-rigged training ship with its maze of lines and its great opportunity for employment of a large crew. Society, it appears, has become too enthralled with a mania to replace human labor with that of machines. As a result, many labor-saving devices waste, rather than "save" labor. On an environic scale, encompassing not only economic but other human disciplines as well, a labor-intensive sailing vessel is a positive achievement. The business of maritime transport in concert with a widespread sail training program would be a spectacular accomplishment for modern wind-powered cargo ships. Designers of these vessels should expand their horizons to encompass these commendable social goals.

PUBLIC SUPPORT

If modern wind-powered cargo ships are to be built, they must attract investors who will build them and employ them in maritime trade. Support for that mode of transport by the general public, although of an indirect nature, should have a positive influence on its development. For instance, this support by the general public will have a positive effect on legislative matters concerning sailing vessels.

The hypothesis that the public will support modern sailing ships is based partly on the immense popularity of

sail as a form of recreation. The number of sailing craft registered in the United States has increased from 598,000 to 992,000 (7.8 percent of all recreational boats) between the years 1973 and 1976.[57]

Perhaps the attraction is that for the spirituality and the relaxing nature of wind propulsion. This is especially important in today's mechanical and automated world in which man has never been so far removed from the elemental forces of nature. Sail recreation will become even more popular as fuel for power boats becomes more expensive and difficult to obtain. Power boat enthusiasts won't abandon the sport of boating easily, and many will convert to sail. They have been touched by the "water connection" and may find an even more satisfying form of recreation with sail.

Another phenomenon which heightened public awareness of sail power was the OPSAIL '76 celebration in New York Harbor on July 4, 1976. Millions of Americans observed the "tall ships" either personally or via television. The public realizes that sailing ships can still cross the oceans, and that they are more than just romantic relics of the past.

Various "Harborfests" in U.S. ports in 1979 confirm a continuing interest and public involvement in maritime activities. As the population concentrates along the coasts, this interest will undoubtedly be magnified. Similar harbor and sail activities are certain to occur

with greater frequency in the future, and sailing vessels will continue to capture the interest of the public.

In summary, modern wind-powered cargo vessels will undoubtedly receive strong support from the public. In event of a catastrophic interruption in foreign oil supplies, the public will indeed be thankful that these vessels exist, as they may become the major means by which ocean trade is carried on.

FOOTNOTES

[1] J. Ron Brinson, "The U.S. Port System," Seapower, February, 1980, p. 29.

[2] Panel on Future Port Requirements of the United States, Eric Schenker, Chmn., Port Development in the United States, (Washington, 1976), p. 15. Hereafter cited as Schenker, Port Development.

[3] W.H. Bunting, Portrait of a Port: Boston, 1852-1914 (Cambridge, 1971), p. 1. Hereafter cited as Bunting, Boston.

[4] U.S. Army Corps of Engineers, The Port of Boston, Massachusetts, Port Series No. 3, (Washington, 1979), p. 16.

[5] Robert G. Albion, The Rise of New York Port (1815-1860) (New York, 1939), p. 42.

[6] Bunting, Boston, p. 3.

[7] Bunting, Boston, p. 4.

[8] Bunting, Boston, p. 2.

[9] Lawrence J. Bradley, "The London/Bristol Trade Rivalry, Conventional History, and the Colonial Office 5 Records for the Port of New York," (Unpublished Doctoral Dissertation, University of Notre Dame, 1971), p. 139.

[10] Bunting, Boston, p. 4.

[11] Wind and current are important dynamic factors for all ships, even today. They can be measured, and the conning officer must estimate their effect on his ship and compensate for them.

[12] Bunting, Boston, p. 7.

[13] Bunting, Boston, p. 218.

[14] Bunting, Boston, p. 217.

[15] Louis E. Cellineri, Seaport Dynamics (Lexington, 1976), p. 1. Hereafter cited as Cellineri, Seaport Dynamics.

[16] Bunting, Boston, p. 217.

[17] Bunting, Boston, p. 7.

[18]Cellineri, Seaport Dynamics, p. 10.

[19]Cellineri, Seaport Dynamics, p. 5.

[20]Cellineri, Seaport Dynamics, p. 11.

[21]Robert G. Albion, The Rise of New York Port (1815-1860) New York, 1939), pp. 402 and 405.

[22]Department of the Army Corps of Engineers, Waterborne Commerce of the United States, 1976, Part 5, National Summaries, pp. 5 and 19.

[23]Schenker, Port Development, p. 19.

[24]Schenker, Port Development, p. 23.

[25]Schenker, Port Development, p. 14.

[26]Richard S. Thoman and Edgar C. Conkling, Geography of International Trade (Englewood Cliffs, N.J., 1967), pp. 129-130.

[27]Schenker, Port Development, p. 4.

[28]U.S. Department of Commerce, Maritime Administration, A Statistical Analysis of the World's Merchant Fleets as of December 31, 1977, p. 157.

[29]U.S. Department of Commerce, Maritime Administration, A Statistical Analysis of the World's Merchant Fleets as of December 31, 1977, p. 157.

[30]U.S. Department of Commerce, Maritime Administration, 1979 Report on Survey of U.S. Shipbuilding and Repair Facilities, p. 81.

[31]U.S. Department of Commerce, Maritime Administration, 1979 Report on Survey of U.S. Shipbuilding and Repair Facilities, p. 42.

[32]Royal Institution of Naval Architects, The Naval Architect, May, 1979, p. 91.

[33]Edwin M. Hood, "Shipbuilding, the SCA, and the Status Quo," Seapower, January, 1980, p. 30.

[34]C. Larry French, "The Gathering Storm for U.S. Shipbuilding," American Merchant Marine Conference 1978 Proceedings, October, 1978, p. 20.

[35]U.S. Department of Commerce, Maritime Administration, Essential United States Foreign Trade Routes, 1975.

[36] J. Ron Brinson, "The U.S. Port System," Seapower, 1980, p. 31.

[37] A bow-thruster is a propeller mounted below the waterline near the bow of a ship. This device is mounted in an athwartship's tunnel built through the hull of the vessel. When energized, it pushes the bow of the ship laterally through the water, either to port or starboard, according to the desires of the conning officer.

[38] Break-bulk cargoes consist of non-uniform units of general cargo stowed in the holds of a ship, which are lifted on or off, piece by piece, by means of cranes or booms.

[39] Trevor Lones, "Getting the Wind Up Over Energy Supplies," Seatrade, December, 1978, p. 81.

[40] Hugh G. Lawrence, "The Western Flyer Project--A Modern Sailing Cargo Ship," paper presented to Society of Naval Architects and Marine Engineers, San Francisco, Sept. 9, 1979, p. 14.

[41] William L. Warner and Miklos M. Kossa, "Updating an Ancient Art--Research and Development Toward Modern Wind Powered Cargo Ships," paper presented to Society of Naval Architects and Marine Engineers Symposium, San Francisco, May 25-27, 1977, p. 3.

[42] Greg Ovechka, "Bulk Cargo Handling Products and Systems," Marine Engineering/Log, September, 1979, pp. 45-52.

[43] Headquarters, Air Force Eastern Test Range, "Joint Army/Navy Balloon Transport System Final Test Report," August, 1976.

[44] Headquarters, Air Force Eastern Test Range, "Joint Army/Navy Balloon Transport System Final Test Report," August, 1976, p. 12.

[45] Dynaship Offices, Palo Alto, California, August 2, 1978.

[46] J. Ron Brinson, "The U.S. Port System," Seapower, February, 1980, p. 31.

[47] International Cargo Handling Coordination Association, "Progress in Cargo Handling," papers read at the General Technical Conference of the ICHCA, Naples, 1954 (London, 1955).

[48] Patrick Finley, Secretary-General, International Cargo Handling Coordination Association to Bruce G. Koltz, December 11, 1978, author's personal files.

[49] Dr. F.A.F. Scheurleer, Managing Director, Port of Rotterdam, to Bruce G. Koltz, October 24, 1979, author's personal files.

[50] Alan Villiers, The Way of a Ship (New York, 1970), p. 167.

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[53] William Warner, Dynaship Offices, Palo Alto, California, August 2, 1978.

[54] William Warner, Dynaship Offices, Palo Alto, California, August 2, 1978.

[55] Alan Villiers, The Way of a Ship (New York, 1970), p. 365.

[56] Barclay Warburton, "Sail Training as a Modern Idea," Tall Ships, '76 (Newport, 1976), p. 21.

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CHAPTER V

SAILING SHIP WEATHER ROUTING

Man's awareness of oceanic wind and weather patterns was essential to his success in early voyaging across large expanses of water. Prior to the advent of the steam engine, the wind was the only means of propulsion available to large ships. The refinement of mariner's powers of observation and the resultant recording and understanding of the wind and other environmental forces was traced in Chapter I. By the end of the great age of sail, ship weather routing had advanced to a science. Even at that time however, decisions regarding weather routing were based upon historical records and a master's talent for interpretation of local conditions.

Today, the science of meteorology is an integral part of ship's weather routing. Based on long range forecasts, optimum transoceanic routes can be planned and modified as deemed necessary by consideration of actual local weather conditions encountered. Meteorological satellites are a vital tool in this process, for both short and long range forecasting.

The application of weather routing to modern wind-powered cargo ships holds great potential for their success in both physical and economic terms.

WEATHER ROUTING BASICS

The basic philosophy and application of weather routing are discussed here briefly as a background for the subsequent discussion on the application of this system to sailing ships.

Present State of the Art

Ship's routing based on present and forecasted weather is a vital phase of both commercial and military ship activities. Modern forecasting methods and instantaneous communications have allowed weather routing to save shippers thousands of dollars in both time and fuel on a single voyage. Additionally, weather routing enhances the safety of ships, crew, and cargoes. Heavy seas and strong winds can endanger even a large, powerful modern ship, and accidents and losses at sea due to adverse weather are all too frequent. In 1976, 22 percent of all ship losses were attributed to weather.[1]

There are two important phases of ship weather routing. The first is voyage planning, which entails the selection of an optimum route. The record phase is enroute monitoring and subsequent advisories for route modification, if required.

The first phase, route selection, is actually a synthesis of meteorological prediction with an analysis

of ship characteristics. Dissimilar ships respond differently to similar weather conditions. Thus, route selection is individually tailored to each vessel receiving weather routing services.

During the enroute monitoring phase, two-way communications between the vessel and the shore facility providing the routing service is essential. The ship master's on-site observation of the weather provides important feedback for analysis of the local conditions. Routing strategy for the remainder of the voyage is thus enhanced.

Weather routing services are readily available for all ships. U.S. Naval vessels may request Optimum Track Ship Routing (OTSR) from Fleet Numerical Weather Central in Monterey, California or Norfolk, Virginia.[2] Commercial vessels may obtain services from several organizations such as Oceanroutes, Inc. of Palo Alto, California.[3] Organizations such as these are computer linked with various private, governmental, and international weather data sources. These highly capable, well-staffed centers can advise ships at sea on a timely basis with modern, long-range communications systems. The advent of remote sensing of weather phenomena from satellites has substantially increased the capability of weather routing services. Satellite technology serves a dual function in this regard as well by also providing reliable communications to ships at sea.

Two basic methods are envisioned for transmission of sea state and weather data to ships at sea. The first is a

data link directly from the sensing satellite to ships. This method requires a system of data interpretation and processing aboard the satellite or aboard ship. In the latter case, raw data would be transmitted to a processor aboard ship, which would provide the mariner with information such as wave height and/or direction, and wind speed and direction for a given area. With the level of microprocessor and computer technology today, the data could be received by ships almost instantaneously. However, the expense of installing processing equipment aboard many individual ships would be very high.

The second avenue for transmission of this data is from the satellite to a shore processing station and then to the ships at sea, probably by means of a maritime communications satellite such as MARISAT. The advantage of this method is that one large, well equipped shore station, receiving data from many sensors, could correlate the information and broadcast more complete weather and sea reports to all ships at sea.

MARISAT appears to be the ideal vehicle for transfer of this data to ships at sea. This is a system of three satellites operated by the International Maritime Satellite Organization (INMARSAT), which was established Sept. 3, 1976. Forty nations are prospective participants, and 70 ships and platforms were using MARISAT in 1977.[4] The system is capable of serving thousands of ships, but a slow start is predicted

for the conservative shipping industry.

The three operational satellites were launched in 1976 and are located at 15° W (Atlantic), 73° E (Indian Ocean) and 176° E (Pacific).[5] Each satellite is in a stationary orbit 23,000 miles above the surface of the earth. The lifespan for each is five years. The second generation system will be called MAROTS and will be administered by the European Space Agency (ESA).[6] Four satellites are planned, each with a life span of seven years. MARISAT and its follow-on system will become an integral part of providing ships at sea with up-to-date weather and sea state data.

It is evident from the foregoing discussion on weather routing and communications that these services are of great value to the maritime industry, particularly sailing vessels. These modern wind-powered ships cannot afford to be "conservative," and ignore the available technology. Their intense efforts to seek and employ every means available for faster and safer voyages will be rewarded.

The environmental factors affecting weather routing and their particular application to sailing vessels are considered next.

Environmental Factors

The effective weather routing of modern wind-powered ships depends upon more than the determination of the wind

velocity. The wind factor is central to this routing process, but other weather phenomena are important to sailing ships, just as they are for motorized ships.

Weather pressure patterns and storm paths are of vital interest due to their effects on the local wind and wave patterns. Sea state[7] data is necessary because of the adverse effect of large waves and rough seas on ship's speed.

Ocean currents are not as visably obvious as the wind, but are also an important force for the mariner to consider. Often, both wind and current work to the advantage of the mariner, but to the contrary, one or both may work to his disfavor. Consideration of current can add a knot, or even half a knot to a ship's speed and can have a significant effect on arrival time in port.

Mariners have relied on seasonal weather phenomena for hundreds of years. The most famous of these is the Monsoon of the Indian Ocean. General knowledge of this condition is certainly useful, but insufficient. Even though average wind speed and directions are known for a certain area during a certain time of year, daily or even hourly variations can cause the "normal" condition to be quite different. The same is true for the trade winds, the westerlies, the doldrums and the zones of variable winds. Historical data on winds only indicate average conditions. Additionally, the boundaries of these wind zones are not always well defined, and they

tend to drift north and south seasonally. The mariner is interested in instantaneous data for his present location or the area which he is about to enter.

Aspects of Routing for Sail Which Are Essential

Any mariner is concerned with the surface winds in the area of his track, but the sailing ship master is absolutely dependent upon the winds. Azad has summed up the strategy of weather-routing of sailing ships as "guide the ship to the seas where the winds are blowing."[8] Of course, certain wind directions will be more favorable than others, and high and low extremes of wind velocity are to be avoided.

A wealth of practical knowledge about the world's wind patterns has been amassed by mariners for hundreds of years. Experience and the science of meteorology have shown that the southern hemisphere, with about 80 percent continuous ocean, exhibits more orderly and simpler patterns of air pressure than the northern hemisphere, which has only about 60 percent continuous ocean.[9] Witness the "roaring 40's" (40° S latitude), westerly winds which accounted for ships heading east on voyages to and from the Orient and Australia from Europe, resulting in a circumnavigation of the globe.

The regions of greatest risk for commercial sailing ships are the transitional zones between the trade winds and the westerlies, and the doldrums between the opposing trade winds. Burger details these areas to a further

degree:[10]

1) The North Atlantic and North Pacific at middle and high latitudes where swiftly moving depressions and the associated area of wave reaction often move across from west to east.

2) Each side of the sub-tropical High, where slowly moving depressions are often in existence in certain seasons, for example, off the Portuguese coast and the west coast of North Africa, and off the southeast coast of the U.S. Atlantic seaboard.

3) Off East Africa, the northerly part of the Indian Ocean and off the China coast, where the starting date of the West monsoon (SW and NW) is most important for sailing vessels.

4) The doldrums,[11] where it is advisable to know their boundaries so that their varying width is known well before the arrival of a vessel in these latitudes.

5) Near Cape Horn where depressions are frequently formed and icebergs can be a danger.

6) Regions where tropical hurricanes can be expected, such as the West Indies, Cape Verde Islands, the China Sea and the Philippines, Bay of Bengal, Arabian Sea, South Indian Ocean, southwest Pacific and near west Central America.

In the above areas, accurate weather, wind and wave data can be of the greatest assistance. Properly placed sea-monitoring satellites should, however, make coverage

of the entire ocean area possible. Modern sailing vessels face the fortunate prospect of developing during a period in which significant advances are taking place in the science of remote sensing of the sea from space.

IMPACT OF REMOTE SENSING

Remote sensing may be defined as the determination of the shape and character of a surface, or the properties of a substance from some distance away without physical contact. Some energy must be transferred between the point under examination and the sensor. In the case of remote sensing of the ocean, this energy is electromagnetic - light, infra-red, radio or microwave.

The term remote sensing is heard increasingly in association with man-made satellites. Sensors employed in weather and surveillance satellites cover extensive areas of the sea surface in short periods of time, relaying information back to earth instantaneously. This is particularly valuable in oceanography and weather routing, activities concerned with conditions over vast areas of ocean. Additionally, the data desired is of an ever-changing nature, so the time period between sensing and data use must be minimal. Thus exists a paradox, albeit a logical one, of studying the oceans from space, rather than from upon the sea surface itself.

Due to the dependence of modern wind-powered ships upon

wind data, remote sensing devices will have a profound impact on the successful weather routing of these vessels. A ship's master can be advised if a more favorable wind condition exists just a few miles off his course. Careful use of this data can result in higher average speeds and faster passages.

The following discussion reviews briefly the existing remote sensing platforms and data available as influences upon weather routing and specifies future needs to support modern sailing ships.

Existing Platforms and Data

During the 1960's, 16 geodesy and 24 unmanned weather satellites were in operation. During the 1978 to 1982 time frame, data about the earth relating to oceanography is being or will be received from several satellites, including TIROS-N, LANDSAT(ERTS), NIMBUS-G, NOAA-A and B (TIROS follow-on), GOES-D(SMS-F), four DMSP-5D satellites, and SEASAT.[12] The latter, the only satellite dedicated to the ocean sciences, failed after three months in orbit in 1978.

Although SEASAT no longer exists in an operational status, it is discussed here because of the ongoing study of the data obtained over its short life-span. The National Aeronautics and Space Administration's Jet Propulsion Laboratory (NASA JPL) launched SEASAT on June 28, 1978. This spacecraft was the first dedicated to establishing the

utility of microwave sensors for remote sensing of the oceans. The satellite circled the earth at a height of 800 Km in a nearly circular orbit 14 times each day, covering 95 percent of the earth's oceans every 36 hours. Data obtained included information on sea surface winds, sea surface temperatures, wave heights, internal waves, atmospheric water, sea ice, ocean topography, and the marine geoid.[13] On October 9, 1978, SEASAT failed after operating normally for 105 days.[14]

SEASAT sensors included a radar altimeter which monitored ocean wave height, a radar scatterometer for sensing surface winds, a visible and infrared radiometer for feature identification and interpretation of data from other sensors, a synthetic aperature radar which measured wave height, and a scanning multichannel microwave radiometer for measuring sea surface temperature, roughness, and wind speed.

SEASAT provided a plethora of data during its short life, much of which remains to be processed. The satellite was very successful in demonstrating the feasibility of putting ocean sensors in space. Oceanographers have learned much from SEASAT which will lead to improved ocean sensors in future satellites.

The GEOS-3 (Geodynamics Experimental Ocean Satellite) spacecraft, which was launched in April, 1975, carries a short-pulse radar altimeter designed to provide an accurate measurement of the distance above the earth, and to determine

the mean roughness of the earth's surface.[15] The latter measurement is obtained by recording the shape of the radar return pulse. Since the satellite operates over the oceans, surface height changes show variations in the earth's gravitational field, and roughness changes are due to waves.

GEOS-3 wave data is being rapidly calculated and is available to users on the Infonet data system, which can be accessed by telephone terminal link. The possibility exists of computing wave height data on board the spacecraft and transmitting on a real-time basis over a narrow band to many users.

Additional experiments with GEOS-3 indicate that the satellite's altimetry data may be of use in determining ocean currents from sea surface topography.[16]

The value of meteorology satellites to oceanography, particularly for surface wind and wave monitoring and prediction is immediately apparent. Better monitoring of existing sea surface conditions, which in turn can result in better forecasts will result in more successful weather routing of ships. Present and planned satellites relating to meteorology include TIROS-N and NOAA-A and B follow-ons, NIMBUS-G, GOES-D(SMS-F), and four DMSP-5D DOD meteorological satellites.

In addition to the obvious value of these satellites, two of those mentioned above will provide significant data to oceanographers and those interested in ship routing. TIROS-N, launched in October, 1978, is expected to provide

data on ocean surfaces.[17] NIMBUS-G, also launched in October, 1978, carries a multiple-frequency passive microwave sensor, such as SEASAT's SMMR, which can obtain surface wind speed.[18] Also among its instruments is an infrared color scanner, expected to provide exceptional pictures of ocean areas and coastlines. Both TIROS-N and NIMBUS-G have also been used in mapping sea-ice.

Shore based stations emitting HF radio skywaves have been used to determine ocean wave heights over large areas up to 4000 Km from shore.[19] Surface radio waves have been used for the same purpose out to 200 Km. This method relies on the return sea echo Doppler strength which has been shown to be dependent on wave-height spectral strength. Wavelengths from 5 to 15 meters can be detected by this method. From this data, wind velocity can be extracted. Research is also being conducted in detection of ocean surface currents by this method. Possibilities of shipborne radars providing this information are also being investigated.

Future Needs

The cornerstone of the information system for weather routing will continue to be manmade satellites. In the absence of sensors designed specifically for ocean reconnaissance, weather satellites will provide the ship-router with a wealth of information. It is important that research be done that 1) improves the quality of the data available

to the mariner, and 2) results in systems that relay the data to the mariner in a useable form on an instantaneous basis.

Due to funding and coordination problems, another SEA-SAT in the future is doubtful.[20] Other platforms will have to be exploited fully by the oceanographer to obtain useful data.

If all the desired data is not yet in hand, the infrastructure for using it is certainly in existence. Oceanroutes, Inc. has indicated that they will be able to route a sailing cargo ship into and along bands of favorable and moderate velocity winds for the great majority of the passage time along certain major trade routes.[21] Specific methods available for this routing are reviewed below.

WEATHER ROUTING OF MODERN SAILING SHIPS: METHODOLOGY

This chapter has examined thus far the basic concepts of ship weather routing, the actual environmental factors involved, and the remote sensing tools available for determination of those factors. This section will examine the factors necessary for applying this information to modern sailing ships. Two specific proposals for sailing ship routing are reviewed herein.

Weather Routing of Sailing Ships as Proposed by Burger[22]

This method correlates detailed characteristics of the ship to be routed with weather encountered along the proposed track. Thus the ship can be routed to take best advantage of its seakeeping abilities.

Burger lists the following ship's characteristics as necessary prior to routing:

1) Mean draft and trim for a particular voyage.

2) Stability curves for various load conditions.

3) The height of the center of gravity for different load conditions.

4) The mean height of center of pressure of the sail area (center of effort).

5) Graphs showing the effect on the speed of the vessel due to wave height, wave period and the relative direction of the wave field. These data may be obtained from model tests in a tank so that wind effect can be eliminated.

6) Velocity diagram showing speeds of travel for a ship as a function of course angle to the true wind for various wind intensities (Figure 28).

After compilation of the above information, actual weather routing can begin. Initially, a general track will be laid out based upon seasonal weather data and the most accurate available forecasts. As the vessel proceeds, up-to-date weather and sea state information can be used to

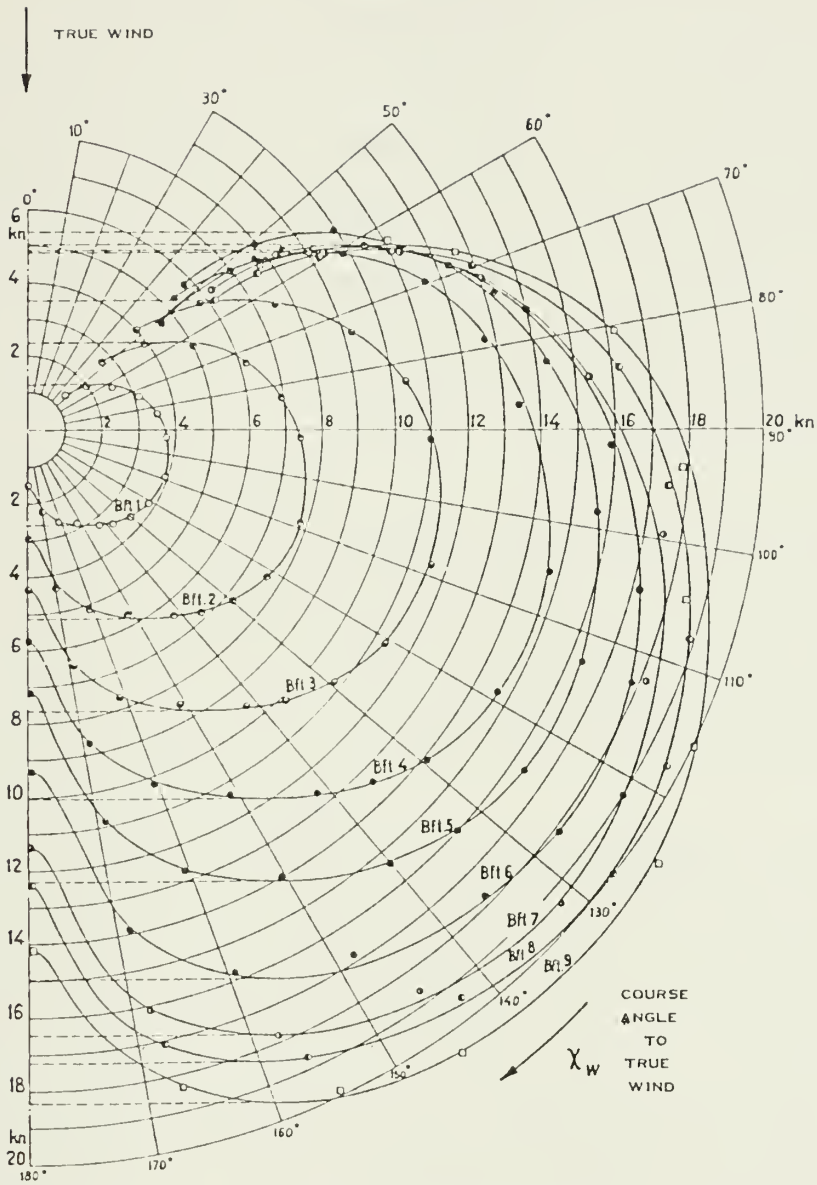

FIGURE 28. Velocity Diagram For 17,000 DWT Dynaship
Source: Dynaship Brochure, Dynaship Corporation, Palo Alto, California, Undated.

"tune" finely the route to attain the best track possible. A particular consideration will be the distance to keep the ship from the center of a depression and its associated area of wave reaction. Here the data concerning the relationships between the true and apparent wind and ship's performance is valuable. The router can then determine the best courses for the ship to steer through the depression and prepare for the next weather phenomenon.

Present forecasted weather data only allows update of weather routed tracks every 12 to 24 hours. More frequent data provided by satellites will make this process even more accurate and will improve the efficiency of modern sailing ships.

This method described by Burger appears to be a logical synthesis of ship's characteristics with wind and wave conditions encountered. The following method by Azad, although similar in some respects, develops a set of rules based upon the relationship between the vessel's course to its objective and the direction of the wind.

Weather Routing of Sailing Ships as Discussed by Azad[23]

This proposal is actually one for determining passage times of a sailing ship using simulated weather routing. However, it does provide insight into three different methods of sailing ship routing using seasonal weather and weather routing.

Azad claims that a sailing ship does not have a speed, but has a potential speed which is a function of wind strength and its direction relative to the ship's head. Again, figure 28 illustrates this relationship. Given this polar diagram, the passage time between any two points can be calculated by simulation in three different ways:

1) Using seasonal weather on the shortest safe route.

2) Using seasonal weather on the optimal seasonal route.

3) By weather routing.

Seasonal weather statistics are published by month for each 5^{o} "field" of latitude and longitude as pilot charts published by the Defense Mapping Agency. Figure 29 shows this data for the Northwest Pacific.

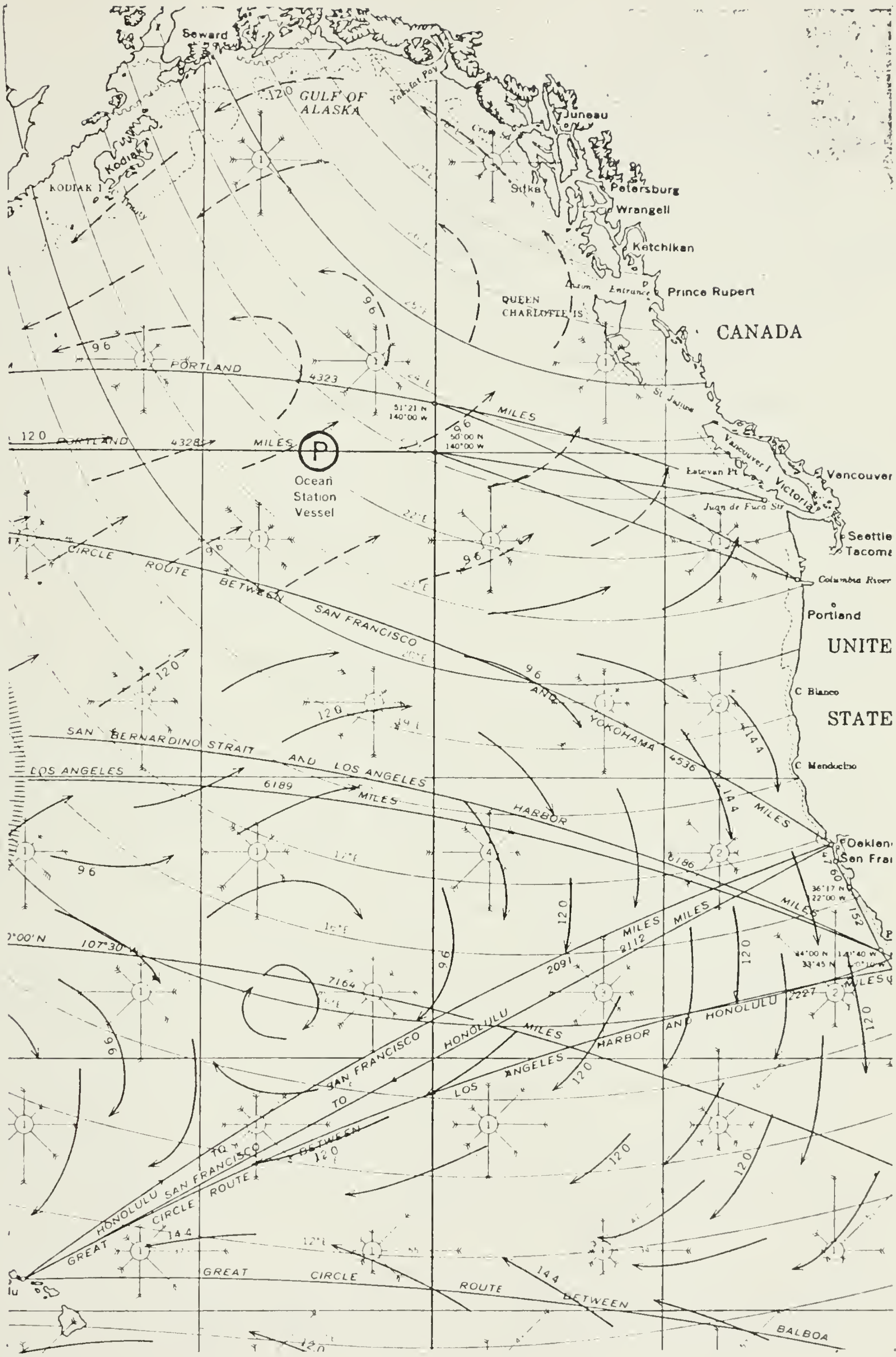

FIGURE 29. Portion of Defense Mapping Agency Pilot Chart for the North Pacific Ocean.

Using the first method, the shortest safe route is laid out and the winds expected in each field are compared with the polar diagrams of the ship and weighted speeds (according to the percentage duration of the chosen velocity) for each field are calculated. Then the mean speed can be calculated from the sum of speeds from each field.

The second method simply alters the track to sail through fields that have the best probability for favorable winds for the given time of year. The speed calculations are then made as in the first method.

The third method, that of weather routing, is the one of most interest. The simulation of weather routing as discussed by Azad will not be elaborated upon here, as the major interest is in actual weather routing to attain the fastest passage, whatever the speed may be. Azad's results and applications are, however, most interesting.

Given that weather phenomena, particularly wind speed and direction, can be remotely sensed instantaneously, the direction of the ship's objective relative to the wind direction can be used to reduce weather routing to a few simple rules. The following definitions apply:

X_o = direction of the objective relative to the wind direction.

X_a = optimum course relative to the wind for progress against the wind.

X_b = optimum course relative to the wind for progress when running before the wind.

Rule 1 - If $X_o = 0^o$, equal times should be sailed on the port and starboard tacks keeping the wind X_a^o on the beam.

Rule 2 - If $X_o < X_a$, then boards (distance sailed between tacks) to be sailed should be with the wind X_a^o to port and starboard, but the duration of the boards should be adjusted to give equal deviation to port and starboard of the objective course, X_o.

Rule 3 - If $X_a < X_o < X_b$, then the ship should be kept on the heading X_o.

Rule 4 - If $X_b < X_o < 180^o$, then the boards to be sailed should be with the wind $(180^o - X_b)$ on the port and starboard quarter and the duration of the boards should be adjusted to give equal deviations to the port and starboard of the objective course X_o.

Rule 5 - If $X_o = 180^o$, equal times should be sailed with the wind $(180^o - X_b)$ on the port and starboard quarters.

Individual ship performance data to determine optimum angles with the wind will, of course, have to be determined during trials. Throughout a given passage, good judgment must be integrated with these rules, as wind speed and direction do not remain constant. Other environmental factors, such as wave height and direction must also be considered, but are not addressed by this method.

As a matter of interest, Azad calculates that a modern

sailing ship, such as Dynaship, will be able to average a speed of about 10 knots between Western Europe and the North Atlantic Seaboard of the U.S. The application of remote sensing as discussed in this chapter will no doubt improve that speed.

In summary, the inevitable reintroduction of modern sailing cargo ships will coincide with continuing application of remote sensing to improve weather routing of ships. This simultaneous occurrence reinforces the already promising technical, economic, and environic arguments for a return to sail.

The foregoing discussion describes the high degree of refinement of wind measurement and prediction for ships at sea. Perhaps the skill arising from this marine application could have application on land as well, for agricultural uses, determination of wind effects in complicated topography, and advanced warning of unusual wind phenomena. Information interchange between these two interests may prove mutually beneficial.

FOOTNOTES

[1]William F. Dupin, "Optimization of Ship Routing," Ship Operation Automation II, ed. Marvin Pitkin, John J. Roche, Theodore J. Williams, (New York, 1976), p. 24.

[2]Naval Education and Training Support Command, Surface Ship Operations, (Washington, 1978), pp. 102-104.

[3]Oceanroutes, Inc., "Oceanrouting," Description of Services, (undated).

[4]"MARISAT Owners Eye European Follow-on," Aviation Week and Space Technology, October 17, 1977, p. 138.

[5]"Difficulties Face INMARISAT Before Operational Status," Aviation Week and Space Technology, November 29, 1976, pp. 15-17.

[6]"MARISAT Owners Eye European Follow-on," Aviation Week and Space Technology, October 17, 1977, p. 138.

[7]Sea state or state of the sea is a descriptive adjective or number used to indicate an increasing scale of wave height.

[8]S.A. Azad, "Calculation of Passage Times of a Sailing Ship by Simulated Weather Routing," paper presented at the Symposium on the Future of Commercial Sail, Small Craft Group of the Royal Institution of Naval Architects, November 28, 1975.

[9]Charles H. Cotter, "Winds, Currents and Sailing Routes," The Journal of Navigation, May, 1977, p. 182.

[10]W. Burger, "Weather Routing of Sailing Ships," The Journal of Navigation, May, 1977, pp. 184-195.

[11]An equitorial zone characterized by calms and light, inconsistent winds.

[12]V.E. Noble, "Remote-Sensing Measurements of Ocean Boundary Parameters," Report of NRL Progress, November, 1978, p. 2.

[13]G.H. Born, J.A. Dunne, D.B. Lame, "SEASAT Mission Overview," Science, June 29, 1979, pp. 1405-1406.

[14]"Communication Problem Cited in Failure of SEASAT Spacecraft," Aviation Week and Space Technology, February 15, 1979, p. 14. Failure was attributed to a massive short in a slip-ring assembly in the Lockheed-Agena bus. This caused the spacecraft's batteries to drain faster than the banks of solar collectors could replenish them.

[15]J.F.R. Gower, "The Computation of Ocean Wave Heights From GEOS-3 Satellite Radar Altimeter Data," Remote Sensing of Environment, 8:1979, p. 97.

[16]R.S. Mather, C. Rizos, and R. Coleman, "Remote Sensing of Ocean Circulation with Satellite Altimetry," Science, July 6, 1979, pp. 11-17.

[17]Igor Lobanov, "Studying the Sea from Space," Oceans, May-June, 1979, p. 8.

[18]Igor Lobanov, "Studying the Sea from Space," Oceans, May-June, 1979, p. 8.

[19]Donald E. Barrick, "HF Radio Oceanography - A Review," Boundary Layer Meteorology, 13 (1978), pp. 23-43.

[20]William A. Nierenberg, "Why There Won't Be Any More SEASATS," Oceans, May-June, 1979, p. 11.

[21]Hugh G. Lawrence, "A Modern Fore-and-Aft Rigged Sailing Cargo Ship," Royal Institution of Naval Architects, Occasional Publication No. 2, The Future of Commercial Sail, 1976, p. 23.

[22]W. Burger, "Weather Routing of Sailing Ships," The Journal of Navigation, May, 1977, pp. 184-185.

[23]S.A. Azad, "Calculation of Passage Times of a Sailing Ship by Simulated Weather Routing," paper presented at the Symposium on the Future of Commercial Sail, Small Craft Group of the Royal Institution of Naval Architects, November 28, 1975.

SUMMARY

The reintroduction of sail has been discussed herein in environic terms as a fundamental national economic obligation. Wind power represents a rational form of energy use in a world which is foolishly squandering its fossil fuel resources. In a purely economic context, modern sailing vessels will allow consumer nations to decrease their dependence on foreign oil supplies. Shipowners will face lower operating costs because sailing ships consume less fuel. In an environic context, a shift toward wind propulsion in marine transport can produce positive consequences by revitalizing small port economies, renewing a fundamental man/nature relationship, and reducing the usage of marine fuels which pollute the seas and air if accidently discharged or burned in normal use.

This thesis has reviewed the historical development of sail, emphasizing certain characteristics of sail propulsion technology that are important for a reconsideration of sail for modern ships. These characteristics are scheduled operations, speed, carrying capacity and economy. The development of each of these in specific ship types was traced.

Proposals for modern sailing ships were discussed, some of which stem from the traditional sailing vessel technology which existed when wind power at sea was overtaken by the

use of steam power. Other proposals rely on modern concepts and technological innovations in the design of modern sailing cargo ships. Another set of proposals are based upon the concept of sail providing auxiliary power for motorized ships.

No matter what type of technology is represented by the first modern wind-powered cargo ships, numerous economic and legal considerations must be taken into account to ensure the continuing success of these ships. A relatively small size is anticipated for these modern sailing vessels, most likely in the 15,000-45,000 DWT range. The first ships will undoubtedly be at the lower end of this size range, with later designs being larger as the feasibility of sail is reproven.

Wind-powered ships, although capable of reaching speeds of 15 knots or greater, will have lower average speeds than motorized ships because of the inconsistency of winds expected over the routes travelled. However, the employment of these ships in bulk trades where continuity is more important than speed of delivery overcomes this disadvantage.

In regard to size and speed of modern sailing vessels, the ships, as proposed, will be equivalent and competitive in size to over seventy-five percent, and in speed to over seven percent of existing bulk carriers. These figures are exceptional for any new mode of transportation at inception.

A reintroduction of sail must take place within the existing legal framework of marine commerce. The discovery

of areas of incompatibility will justify necessary changes. Important areas of legal consideration include ship licensing and classification, registry, navigation rules, safety, and insurance.

The impact of greatest consequence will be the effects of modern wind-powered ships on small port economy. These vessels will signal a move away from the recent trend toward gigantism in ships. Large, deep draft, highly specialized shipping has concentrated ocean trade in a few superports or load centers, resulting in the economic disadvantage of many smaller ports. Distribution of goods from these main ports depends upon more energy intensive modes of transport, which is simply not rational in an energy-short world. It is trade with these now bypassed ports which demonstrates the most profound contribution of modern wind-powered cargo vessels. Shipbuilding and repair facilities in and near these ports will experience a like revitalization.

The basic relationship between man and the natural forces of wind and water will be rekindled by a return to wind propulsion. A ship so closely tied to the natural forces cannot help but involve her crew with these same forces in a most intimate way. The prospects of incorporating sail training with commercial sailing ship operations is an exciting way to involve youth in this most fundamental environic relationship.

The sciences of remote sensing of the sea's waves and

surface winds and instant communications hold great potential for the improvement of weather routing of modern sailing ships. Armed with instantaneous weather information, masters of these modern vessels will be able to take maximum advantage of wind and weather to make the fastest passages possible. Thus, wind-powered ships will become increasingly competitive with motorized ships.

The reintroduction of wind-powered ships will not act as a general panacea for all the problems of the shipping industry. It will be, however, complementary to other efforts now underway to improve the fuel efficiency of ships at sea. Time sensitive cargoes will continue to be moved by fast ships. Economy of scale will undoubtedly dictate that petroleum be transported in supertankers as long as the oil economy exists. Therefore, research concerning more efficient diesel and steam propulsion plants should proceed as another important alternative.

The advantages of sail power for the commercial aspects of marine transport are numerous. Somewhat more controversial is the applicability of sail power for naval use. Naval forces are, in their primary mission, dependent upon speed, reliability, maneuverability, and an array of technologically advanced weapon systems. Although naval battles were once fought under sail, a sailing naval ship today would be at a disadvantage when operating with or against modern nuclear, steam, or gas turbine-powered ships.

Another less obvious, but equally important mission of naval forces is logistics, the transport of military cargoes in both peacetime and wartime. During an emergency or contingency, time-sensitive cargoes must be transported by motorized ships, at least when the assumption is made that fuel will be available. However, the Commander, Military Sealift Command, that branch of the U.S. Navy committed to providing effective, efficient, and economical sealift capability to support U.S. military forces, states that in peacetime, "A wind-powered ship might well have value in meeting that commitment."[1] Approximately 95 percent of the volume of material and equipment upon which the U.S. Armed Forces depends must be delivered by sea.[2] This is a naval situation in which wind-powered ships may potentially perform useful service.

An interesting proposal for use of wind-power by naval vessels in a tactical situation has been suggested by Morisseau.[3] He introduces the use of sailing hydrofoils as an ideal vehicle for anti-submarine warfare, stating that "From a purely tactical point of view the quiet movement, without the clatter of machinery or the cavitation of propellors, makes the sailing ship an ideal Anti-Submarine Warfare (ASW) platform."[4] His proposal includes a design for a small (approximately 500 ton) hydrofoil with a rigid airfoil propulsion system. The idea is promising and should receive research support from the U.S. Navy.

Sail training, which is an integral part of naval officer training in many maritime countries has not received a great deal of attention in the U.S. Navy, where sail training has been limited to schooners, sloops, and yawls up to 80 feet in length. The height of sail training in the U.S. is represented by the U.S. Coast Guard's sail training vessel Eagle.

In March, 1980, the U.S. Navy promulgated an official policy on a sail training program administered by the Naval Education and Training Command.[5] The objectives, in addition to teaching seamanship skills, are to develop leadership and teamwork and an appreciation for the environment of the sea. It is highly significant that the U.S. Navy has officially recognized the need for sail training. Hopefully this event will initiate a Navy-wide awareness of the value of sail training and help establish a more intensive program of sail training for officers.

In summary, the U.S. Navy can and should exert a direct influence on raising sail consciousness for society in general, through 1) initiatives in promotion of ideas for others to confirm, 2) making available naval facilities to test ideas for general application, 3) development of sail power for direct naval application, and 4) making available the brainpower, experience, and enthusiasm within the naval community to further the above goals. These four potential contributions describe the Navy's ability to stimulate ideas and test practical applications toward the development of

this fundamental factor of transportation economy - the wind. Since the globe is three-fourths water-covered, it follows naturally that the obligations of the U.S. Navy include the encouragement and practical reinvestment in the sail.

The basic philosophy of sail power is based upon an environic sensitivity and an obligation toward the condition of both the natural and the man-made environments. Interdependencies between sailing ships and the social and industrial fabric with which they interrelate are of primary importance. Each physical design and social decision regarding modern sailing ships will have environic consequences. Maritime planners are thus obligated toward the cultivation of quality and stability. The advancement of sail consciousness in the public mind is now a fundamental economic obligation with respect to environics, small port economy, and gratifying, profitable employment in the shipping and shipbuilding and repair industries; industries bringing social revitalization to the many ports originally associated with sail economy.

There is a demand for more ships, especially bulk carriers. The technical and economic feasibility of sail has been demonstrated. Physical results, however, are lacking. This, unfortunately, is a familiar feature of modern economy. Parallel circumstances may be found in the search for personalized rapid urban transportation, rapid long distance terrestial transportation, and economic mass produced solar

conversion units. Economic pressure is the ultimate force which produces the technological innovations required to meet these urgencies. That pressure is certainly being felt in the marine transport industry today. Economic pressure is all pervasive, ever present, and wayward - like the wind.

The revival of sail represents the first instance in which technology has advanced toward mechanization, then advanced beyond it in terms that will bring increased respect for those of previous generations. The mariners of tomorrow will deal with the same elements as the wind-ship sailors of yesterday, with renewed respect for their extraordinary tenacity and skill. In no other technology has it yet become necessary to respond again to the power of the natural elements. In this instance, the advance to a more direct and fundamental use of natural forces will result in substantial economic benefits.

FOOTNOTES

[1]Commander, Military Sealift Command, Department of the Navy, to Bruce G. Koltz, October 31, 1979, Author's Personal Files.

[2]Commander, Military Sealift Command, Department of the Navy, to Bruce G. Koltz, October 31, 1979, Author's Personal Files.

[3]Kenneth C. Morisseau, "Why Not Sails?," Naval Engineers Journal, October, 1978, pp. 57-62.

[4]Kenneth C. Morisseau, "Why Not Sails?," Naval Engineers Journal, October, 1978, p. 58.

[5]Chief of Naval Education and Training, Pensacola, Florida, Instruction 1520.10, "Sail Training Program," March 28, 1980.

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